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ALFRED J. HENRY, Editor.

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THE EARTH'S ATMOSPHERE AS A CIRCULAR VORTEX.

By ANNE LOUISE BECK.
[Berkeley, California.]

Miss Anne Louise Beck, of Berkeley, Calif., received one of the Fellowships awarded by the American-Scandinavian Foundation of New York. This Fellowship carried the privilege of a year's study of weather forecasting at the Bergen Geophysical Institute of Bergen, Norway, under Profs. V. Bjerknes and B. Helland-Hansen.

On her return to this country, Miss Beck has kindly authorized the publication of the following account of her studies at Bergen.—EDITOR.

SYNOPSIS.

The general circulation of the atmosphere considered as a circular vortex, as postulated by Professor Bjerknes is briefly discussed; it is pointed out that surfaces of discontinuity must arise along the margins of air streams moving equatorward and poleward, respectively, and that under certain conditions these surfaces of discontinuity are unstable, a wave motion sets in with the cold air pressing southward in the rear of warmer air moving northward; thus a series of wave motions in the atmosphere originate and are propagated eastward.

The criteria are given for fixing the position of that surface of discontinuity to which the name "polar front" has been applied, and the effect of differing conditions which arise in nature in connection with the changes of position of the polar front is discussed in some detail. The occurrence of cyclones in groups or families of two to six, with four being the most probable number according to the statistics of the Norwegian weather maps, is discussed and several families are considered in detail.

The forecasting of the weather of Norway by the Bjerknes theory, as carried on at Bergen, is described for representative weather types and finally an attempt is made to apply the Bjerknes theory to the synoptic weather maps of the U. S. Weather Bureau for January, 1921. The observational material printed on these maps lacks much of the data available in the Norwegian Meteorological Office, nevertheless surfaces of discontinuity can be traced and more exact and detailed forecasting seems to be possible when more detailed observational data are available.

When we consider the motion of the atmosphere, in reference to coordinates which do not participate in the rotation of the earth, we may assume for the sake of simplicity that the earth is at rest and heated by a sun in the form of a ring in the earth's equatorial plane, then we have the well-known scheme of circulation only in the meridian planes. Insolation at the Equator, radiation toward space at the poles causes the isobaric surfaces to slope from the Equator toward the poles in the upper atmosphere. According to Professor Bjerknes's theory of circulation,[1] polar air flows at the surface of the earth toward the Equator, and equatorial air in the heights toward the poles.

The insolation at the Equator then, overcompensating radiation at the same place, causes the air to ascend, whereas radiation causes cooling and, consequently, descent of the air at the poles. This circulation develops until it becomes constant. Polar and equatorial air are thus seen to be separated by a discontinuity.

This picture is modified by the rotation of the earth and a "planetary vortex"—as Professor Bjerknes has named it—is formed. The southerly upper-air current is deflected eastward by the rotation and gives in lower latitudes the antitrades, the northerly current by the same force is deflected into the easterly trades. They are separated by a surface of discontinuity, "the sliding surface of the trades," which according to the formula of Margules (and in its extended form by Bjerknes), slants upward from the Equator. Part of the upper current is sufficiently cooled to be forced to descend in the region of the tropical highs. That the cooling actually takes place is proved by the fact that the temperature at the latitude of the tropical highs is lower than at the Equator in a higher level. A surface circulation from the tropical highs toward the Equator forms part of the cycle in each hemisphere inclosed between the tropical highs and the Equator. The rest of the upper current below the stratosphere continues to flow northeastward and eastward as the upper part of the main westerly current of the Temperate Zones. Part of the latter also emanates from the tropical highs.

At the poles, especially over the high plateau lands of Greenland and the Antarctic Continent the polar cooling is especially efficient, finally transforming the original equatorial air into the outflowing current of polar air. The easterly surface winds at the poles, together with the theoretically necessary winds of westerly component in the outflowing upper current and the difference in temperature, develops a second surface of discontinuity, "the polar sliding surface" which according to the Margules-Bjerknes formula slants upward toward the higher latitudes forming the "polar calotte" of Helmholtz.[2] The difference in temperature at a given level between an air column over the central part of the polar calotte and another at its border, according to the Bjerknes's circulation theorem gives rise to a closed circulation, descent in the central part of the polar calotte, outflow at the ground, forced rise at the polar sliding surface, and inflow in the heights. Thus there are for each hemisphere three circulations "running like cogged wheels."

A surface of discontinuity sloping north-south with easterly cold winds below it on the northern side of its intersection with the earth's surface and warm westerly winds above and to the south is unstable. A wave motion sets in with the cold air pressing southward as a "spreading cold tongue" and warm air running northward ascending the surface of discontinuity as a "warm sector." As in wave motion in any fluid with appreciable friction of viscosity, these waves have a marked life cycle with characteristic stages of development.

[1] V. Bjerknes: On the Dynamics of the Circular Vortex with Applications to the Atmosphere and Atmospheric Vortex and Wave Motions, Christiania, 1921, *Geofysiske Publikationer*, Vol. II, No. 4.

[2] All the air inclosed by the sliding surface and the surface of the earth at the poles.

The life cycle begins with a mere waver in the line of discontinuity, becoming more and more marked as the cold air forces southward, finally curving into spiral-formed "breakers." [3]

In the course of this process the warm air is at last embedded in the cold and cut off from its supply. It will continue poleward in the upper air, while cold air spreads down toward the Equator. Thus this wave motion in the sliding surface is a necessary link in the general circulation. The stronger effect of the deviating force of the earth's rotation at higher latitudes, as well as the greater contrast in temperature between the air masses of different origin to either side and the fact that the polar sliding surface cuts the earth's surface, ought to give the wave motion in question a more conspicuous character at higher latitudes than nearer the Equator. The investigations of the Geophysical Institute at Bergen have confirmed these general conclusions.

The intersection between the polar sliding surface and the surface of the earth has the character of a line of discontinuity in the fields of temperature, as well as in pressure and wind. The investigations of J. Bjerknes, H. Solberg, and T. Bergeron proved the existence of such a line, for which the appropriate name of "polar front" was adopted.

The germs [4] of the theory are contained in Dove's theory of the struggle between equatorial and polar currents. In a theoretical paper Helmholtz has developed the idea that there is always a tendency toward the formation of a surface of discontinuity between the cold polar air tending toward the Equator and the warm equatorial air tending toward the pole, while the cyclone consists in a kind of "rolling up" of this surface. Similar views have been taken up in theoretical papers by Brillouin and by Margules. Sir Napier Shaw has arrived at the same result from the empirical side.[5]

The polar front is a line of demarcation between two air masses, one of Arctic origin, the other flowing from the horse latitudes. As a rule this line can be followed through all the centers of the cyclones of the circumpolar zone of LOWS. Between the centers it makes a long swing toward the south. The movement in the front is usually experienced as a cold front (squall line) southward; the movement northward as a warm front (steering line).

The following facts may be regarded as indicating the position of the polar front: First, discontinuities of temperature found on the synoptic chart; second, temperature variations at stations passed by the polar front; third, trough lines in the field of pressure and corresponding discontinuities of air motion; fourth, tendencies in the pressure record; fifth, rain areas along the polar front; sixth, precipitation at stations passed by the polar front; seventh, amount of and form of clouds; eighth, fog and haze; ninth, discontinuities and variations in absolute humidity.

There are special phenomena to note under these headings, as follows:

(1) The difference in temperature along the polar front in autumn and in winter usually is rather marked, about three or four degrees Centigrade between adjacent stations on the two sides of the front. In spring and in summer, the discontinuity of temperature at the surface of the earth may have disappeared, the temperature differences in summer, upon the whole, being much smaller than in other seasons because insolation, cloudiness, precipitation, distribution of land and water, etc., exert a stronger influence upon the temperature of the air masses at the surface.

(2) In the vicinity of the low, the polar front is almost always accompanied by pressure formations in the form of a trough. Often the troughs are well marked; sometimes, however, they can only be seen when a close network of stations is used. Sometimes convergences of the wind are the only signs of these troughs. At the slowly moving parts of the polar front between the cyclones the troughs for the most part are missing, and the wind may be the same on either side of the front.

(3) The trace of the barograph is one of the best criteria in fixing the position of the polar front. In front of the steering line pressure drops rapidly; at the passage of the line the fall suddenly ceases and the curve becomes nearly horizontal. When the pressure falls also in the warm sector this often indicates the LOW is deepening; when the pressure rises in the warm sector the low is often filling up.

In front of the squall line [6] there is often a slight drop in the pressure, then at the passage of the line the pressure suddenly rises.

The falling pressure in front of the squall line may be altogether lacking. Barometric tendencies in synoptic representation are very useful in fixing the line of demarcation.

The typical warm-front passage shows a barogram with a fairly sharp downward deflection. It is often accompanied by a strong gust of suddenly veering wind, the precipitation diminishes rapidly, passing to fog and drizzle or even to cloudy humid weather, while visibility sinks to a low degree owing to the dust-laden tropical air. The typical cold-front passage is indicated by an upward deflection of the barogram.

(4) and (5) Rain areas form at the boundary of the warm tongue where the warm air ascends above the cold. At the center of the low, two rain belts start, one along and in front of the steering surface, the other accompanying the squall line, generally to the rear of it. The first is usually 200 to 400 kilometers broad, the other seldom more than 100 kilometers, often only 10. With a close network of stations these rain belts are very good indications of the polar front positions. On using the observations of precipitation it should always be borne in mind that orographical conditions play an important part in the formation of rain.

Precipitation is almost always found at stations where the polar front has passed. Only in the outermost part of the cold tongue, the front may pass without causing precipitation. This may also be due to protection by topography.

The cold front is followed by a belt of precipitation in the form of showers often with thunder and hail or soft hail—if the temperature contrasts are strong enough. This stripe of precipitation is always narrower than the rain area before the warm front.

(6) In front of the first rain belt, there is a broad zone, about 300 kilometers, of cloudy weather. The cloud forms in this zone are cirro-stratus and alto-stratus, sometimes the tufted cirrus are the first signs of approaching rain, approximately simultaneous with the beginning of the fall in the barogram. In the warm sector the usual succession of cloud forms is strato-cumulus, stratus, fracto-stratus, but often it is clear. By and by, marking the approach of the cold front,

[3] Fig. 28, p. 80, V. Bjerknes: On the Dynamics of the Circular Vortex, etc.
[4] V. Bjerknes: On the Structure of the Atmosphere when Rain is Falling. *Quarterly Journal of the Royal Meteorological Society*, April, 1920, p. 128.
[5] Fig. 10, p. 129, loc. cit.

[6] Since squalls are frequently absent in connection with this so-called line in the United States, the expression "wind shift" line is to be preferred.—EDITOR.

lenticular alto-cumulus may occur, later changing to alto-stratus and nimbus. In most cases, the weather is overcast a hundred kilometers ahead of the rain front. The rear of the squall line is marked by cumulo-nimbus, cumulus, and fracto-cumulus.

The foremost discontinuity (in the direction of the propagation of the cyclone) the so-called warm front or steering line marks the course of the warm air traveling up the slope of the polar sliding surface. When this warm moist current of tropical origin [7] ascends, it is cooled adiabatically and cloud formation takes place. The "optraek," [8] before an advancing cyclone generally consists in a series of cloud forms beginning with cirrus or cirri in tufts merging into cirronebula with the common optical phenomena followed by cirrostratus, alto-stratus, and lastly the nimbus (pallio nimbus) of the rain belt just preceding the warm front.

As will be seen these cloud forms follow each other from higher to lower levels, and as the sequence is a continuous one already proves that they are the effect of dynamical cooling caused by travel along a slanting surface. It is further proved by aerological observations * * * from the close net of stations in Flanders during the war that this surface really exists in wind, temperature and humidity.

(7) Directly behind the steering-line, especially when the wind velocities are small, fog is often to be found, due to the presence of warm air above the cold surface. Also along the slowly moving part of the polar front (at the southern end of the tongue of polar air) fog occurs. Haze is to be found almost exclusively on the southern side, especially marked, immediately preceding the squall-line.

(8) The polar air is dry and the equatorial air quite humid. Good visibility is a normal characteristic of polar air, though it sometimes happens that the polar air is also polluted—that is, when it has traveled a long way over northern France and England before it reaches the western coast of Norway.

Finally, the following method in fixing the position of the polar front may be used. The front having been surely marked on one map, its future position may be calculated from the gradient wind at the rear, considering both direction and velocity. This is not quite true for steering lines, the air at the rear of them in general moving more rapidly than the line itself. In the case of squall-lines this rule works very well, however, because the air behind the line can not possibly move faster than the line itself. This method is to be used especially when the front has arrived in districts where only few observations are available.

The first investigations concerned discontinuities in moving cyclones of the Temperate Zone, as they are experienced in northwestern Europe, and especially Scandinavia, which is a convenient place for the study of this phenomena.

It is no mere chance, in fact, that the existence of the polar front was first proven for the western coast of Norway, that coast being perpetually swept over by waves in that front.

It should be added that cyclones generally come from the west, but they may come from any point of the compass and actually have been shown to so move in the three years' forecasting, according to the Bjerknes principles which have been practiced in Scandinavia. This is due to the varying position of the polar cap during different periods [9] and under different conditions.

The first cyclone model, described by J. Bjerknes in his paper on "The structure of moving cyclones," [10] refers to a wave in the polar front in the medium stage of its development or life cycle. It soon proved impossible, however, to apply this first cyclone model in all the actual cases of forecasting. Further analysis led to the tracing of unbroken polar fronts from cyclone to cyclone and showed the existence of waves in all stages of development.

In the life cycle of a cyclone the principal stages of development may be represented by Figure 31, page 88, V. Bjerknes: On the dynamics of the circular vortex, etc. The birth is indicated first by a slight curving in the front between two air currents of 180° difference in direction. The pressure is falling, the winds weak and only indicate a tendency toward circulation around a hardly appreciable center. The young cyclone has the form of a water wave with a broad base in the second stage, though its pressure field is still very flat. The propagation of the cyclone in these two early stages is generally rather slow. The third stage is the model referred to above from the paper by J. Bjerknes. The rate of progress at this stage is rather great and velocities of 150 kilometers (93 miles) an hour have been experienced in Norway for cyclones from the Atlantic Ocean.

The point of intersection of the two fronts lies well to the center of the cyclone. The area of warm tropical air between the two fronts is the so-called warm sector. It is characterized by little precipitation, unless it be in the form of fog or drizzle when the warm air is very moist and flows over colder water. If the warm sector comes over a part of the earth's surface where the air has been heated considerably and is already warmer than the air of the warm sector, precipitation may occur in the form of slight occasional showers due to the resulting instability. As regards the weather experienced by different places, according to their situation relative to the moving cyclone, reference is again made to the paper by J. Bjerknes, "On the structure of moving cyclones."

The decline of the cyclone is marked by the tendency of the cold front to gain on the preceding warm one on the equatorial side of the center. As the cold front overtakes the warm the cyclone becomes a "seclusia" (Bergeron) [11] and the warm sector is now cut off from its supply of warm tropical air. A continuation of this motion carries the cold polar air in the rear of the wave up the discontinuity surface of the warm front. This process, with the attendant destruction of the warm-air supply causes the warm-front precipitation area of the cyclone to diminish, while the discontinuities of pressure and wind may still exist at the surface of the earth for some length of time. This is the case which Bergeron calls the "upper front."

In the final stage the warm front is overtaken by the cold throughout, and the cyclone has become an "occlusia" (Bergeron), its warm sector existing only in the upper air as an isolated mass inclosed by polar air. This warm sector becomes more degenerate until the cyclone is thermically dead, its discontinuities no longer apparent

[7] The expression "of tropical origin" must not be taken too literally. It must frequently happen that the warm air in front of a cyclone only a day or so previously came from high latitudes on the front of an anticyclone.—EDITOR.

[8] We have no word among our meteorological terms which exactly translates the Norwegian word "optraek," the complete succession of cloud changes before a storm. * * * Professor Bjerknes, as chairman of the committee for the investigation of the higher atmosphere of the League of Nations has in his keeping records from aeroplane, kite, and balloon ascents covering nearly the whole period of the war, French and English observations as well as copies of material captured from Germany.

[9] There is a striking relation between the position of the polar front marking the boundary of the polar calotte and the southward extension of the ice fields which in the winter of 1920–21, for example, were far south in the Labrador Straits while the Iceland-Spitsbergen Gap was practically free.

[10] MO. WEATHER REV., February, 1919, 47: 95–99.

[11] Statements arising from discussions in the laboratory.

either at the ground or in the upper air, yet such a dying cyclone has often a powerful wind field apparent at the surface. Doctor Calwagen, at the Bergen Institute, has suggested this may be explained as follows:

The newborn cyclone, with its broad warm sector, represents a great amount of potential energy due to the temperature contrasts between polar and equatorial air, but it has relatively little kinetic energy. During the life cycle this potential energy is transformed into kinetic and the kinetic energy is transformed into heat by friction, external as well as internal, and we have the often very strong wind field in the apparently dead cyclone. It should be observed in forecasting, therefore, that an old cyclone, due to its kinetic energy, acts as a "dynamic shelter" against new cyclones with less strongly developed wind fields.

These forms of cyclones above described follow each other constantly. Moreover, it has been recently found that they follow each other in series or "families." During the early months of 1921 an attempt to count and classify these waves was made at the Bergen Institute.

A number of earlier investigations had been made[12] which are reviewed by Hann.[13] These investigations are, for the most part, more of a statistical nature dealing with amplitude and time intervals of pressure variations. They are not in the nature of thermical or dynamical discussion, therefore are not closely akin to our subject. A suggestion along the same lines was made by Exner[14] in which he spoke of the probable periodicity of cold outbreaks in northern America, in the area about Iceland, Greenland, and Norway, and in an area including Spitzbergen, northern Norway, and Nova Zembla. He speaks of cold outbreaks followed by rainy periods without discussing the matter fully.

At an informal discussion at the Bergen Institute when the fact was noted that very strong cold outbreaks were followed by new cyclones in higher latitudes than the last of the preceding series, the question arose as to the possibility of a cold wave closing a series and after the cold outbreak the arrival of a new. The first wave of the series was jestingly called "Protesilaos." The discussion led further and it was suggested that there seemed to be a preferred number of waves in a series; Mr. H. Solberg considered the number to be four according to his observations.

The above discussion led to the earnest attempt to count and classify these waves. The series of 14 families of January, February, and March, 1921, seem to indicate the number is really four where the waves come from the westerly or southwesterly direction. There was one example of a southwesterly series from March 7 to March 12 confined to three waves. From March 12 to March 20 a south-southwesterly type occurred with as many as six in the series.

The westerly type is a common winter type, which evidently originates west of Iceland in the Atlantic or, rather, one should say, first appear on the synoptic charts of Norway in that portion. They are probably generated by cold air currents over Greenland which come down against the warm air over the Gulf Stream and are characterized by broad warm sectors emphasizing the fact that these cyclones are born within a relatively short distance from Scandinavia. This type is prevalent when the tropical highs over the Atlantic have a great east-westerly expanse and lie rather far to the north.

The southwesterly type is characterized by more occluded warm sectors when the first of the series appears on the chart, thus indicating a birth farther off than in the westerly type.

The first of the series passes often to the west of Iceland through Denmark Sound or over the western part of Iceland. Though nearly occluded, these first waves are often marked by long tails which sweep over the western part of Scandinavia giving rain and strong winds in favorable points, as against a prominent headland where a distortion of the cold front causes the so-called "corner effects."

The waves following generally have better developed warm sectors, as the cold air in front of the first one is swept away. The fourth is often the strongest and draws after it the strongest outbreak of cold air. This gives either anticyclonic conditions confined to the North Atlantic or a wedge of high pressure extending southward to the tropical highs.

The last cyclone thus being a deep one, generally has several cold fronts or squall lines marking the steps of advance of the cold outbreak. One of these secondary squall lines may give rise to one or more secondary waves. The generation of these secondaries generally takes place over southern England or France—though if the area of general circulation is perceptibly moved, for instance, far to the north, these secondaries, too, develop farther north. An example of this is found in Series 14, D wave (April 4 and 5, 1921).[15]

At their first appearance these secondaries may seem very innocent and diffuse, often difficult to detect in the charts, but may develop into deep depressions. These are the real rain bringers in central Europe and in some cases also in Sweden (13 D 1a).[15]

The third wave in series 11, 11C [15] has a remarkable secondary. The third squall line of this depression, 11C, marked a heavy outbreak of cold air over Ireland (March 10, 7 p. m. chart [15]). On that chart the primary had moved as far north as Lafoten. The transport of relatively warm air by winds at the rear, together with the low temperatures as the squall line swept over Ireland built up a very large quasi-warm sector, accentuated as it traveled northward by the contrasts of air relatively warm and air lying over the Arctic Ocean (Spitzbergen $-31°$ C., Bjorn-oen $-5°$ C. in the polar air, in the warm sector the temperatures average $+7°$ C. to the north, $+10°$ or $11°$ C. in the south). That secondary consequently grew to a very strong cyclone, deepening from 749 mm. in the center to 732 mm. by the time it had passed Spitzbergen. Its warm sector had diminished but it remained strong enough to reach much farther north, probably even to the North Pole. During the passage the temperature at Spitzbergen increased to $-5°$. This was at the center of the cyclone. With the passage of the warm sector at Bjorn-oen, the temperature rose to $+3°$. This cyclone was a good example of those which have been experienced passing Franz Joseph's Land by different observers.

During the formation of these secondaries the cold front in which they form becomes stationary in that part or moves slowly as a whole, corresponding to the behavior of the polar front of the mother "calotte" in the formation of new cyclones. This is of vital importance in forecasting. Northwesterly outbreaks, which are usually accom-

[12] W. J. S. Lockyer: Southern Hemisphere Surface Air Circulation, London 1910—Publications of the Solar Physics Committee.
Arctowski: Resultata du Voyage S. Y. Belgica, 1897–1899.
Minardus: Deutsche Südpolarexpedition, 1901–1903, Band III, Meteorologie I, 1, S. 33.
Bodman: Schwedische Südpolarexpedition, 1901–1903, Band III, 4 S. 17.
[13] Lehrbuch der Meteorologie, Book II, Kapital IV, p. 200.
[14] Exner, Dynamische Meteorologie, 1916.

[15] Synoptic charts, Bergen Weather Bureau.

panied by strong squally winds, absolutely require storm warnings, but it often happens that these outbreaks fail, due in the cases especially reviewed to just the above-described and partly unexpected formation of a secondary in the awaited cold front.

On the 8 a. m. chart for February 9 (Synoptic charts, Bergen Weather Bureau) a squall-line was lying east of Iceland, with a rising tendency in the pressure in some places of as much as +7 mm. in three hours. A storm warning was issued for the coast from Bergen northward. The expected gale did not come, but on the 2 p. m. chart of the next day a secondary was revealed forming southwest of Lofoten. This secondary gave a southwesterly prefrontal gale for quite another part of the coast.

Secondaries occur in both the southwesterly and westerly types. The series may or may not be marked by them. Perhaps we think they are lacking only because they have not been detected on the chart. The question is certainly open to much discussion and study.

The type termed southerly, or more properly south-southwesterly, is more of a spring or summer phenomenon in contrast to the winter westerlies. The series is marked by long occluded waves, seldom by waves having a well-developed warm sector. They extend from a stationary center to the south of Iceland south over England and France. These waves are probably generated farther south than those of the series mentioned earlier in this discussion. The general trend of the isobars is north-south and the extended valley of relatively low pressure south of Iceland is an effective shelter against the protrusion of cold polar air under warm tropical, until somewhere rather far south of Cape Farewell.

The tropical high in this case generally is pushed eastward until its center lies near Spain and the Mediterranean. The high is accentuated. This is partly due, in all probability, to the descent of the outflow of air in the upper strata from the cyclones to the west of the high. The length of the path of the cold air from this source to its turning point and back toward the British Isles naturally exhausts much of its original potential energy. The temperature difference between polar and tropical air is less marked under these circumstances, and on this account the cyclone is poorly developed in the beginning, and consequently after its journey northward is still feebly developed, which is seen by the dimensions of its warm sector, the boundaries of which then, especially in the more central parts of the cyclone, between Iceland and the British Isles, are clapped together.

Secondaries also occur in the southwesterly type, although of a somewhat different nature than in the westerly type. Apparently every primary wave has secondaries which appear first over England and France as quasi-warm sectors attached to the occluded primary. The origin of these secondaries is in reality not so far different from the origin of the secondaries in the types mentioned above.

The occlusion has the character of a so-called cold front, advancing from the south-southwest although the instability of the cold air over the warm surface is less marked. When the cold front advances against air that is warm enough in comparison with the polar air, a warm or quasi-warm sector is formed in that part of the cold front. This generally is the case over south England and western France. This is also characteristic of the secondaries of the first-mentioned types. Showers follow the passage of the occluded wave, indicating the unstable nature of the air.

Secondary cyclones often originate in a well-developed cold front. This may occur after the third wave, but more especially the fourth of a series, because these sweep so far south that they come up against air warm enough to feed a warm sector. These secondaries may often have a very innocent aspect upon their first appearance on the synoptic chart, but develop into cyclones with gradient and wind field exceeding that of the primary cyclones. This is the case especially in summer, when the general circulation is less accentuated, with the regeneration of old "secluded" cyclones or cold fronts which have been nearly obliterated but may be revived by a renewal of the warm air supply from a warm continent. It may also happen that new fronts are developed in the cold polar air of a recent outbreak, when the air has been sufficiently warmed in parts to give enough contrast in temperatures. Thus, also, new fronts may develop along the coast of a continent in the winter time due to the contrasts in temperature between the cold air masses of an anticyclone cooled by radiation and the relatively warm air over the adjoining sea or ocean. For instance, such a "maritime" front gave the snowstorm of 500 millimeters of precipitation at Bergen in November, 1919. Secondary fronts in summer frequently develop over Denmark and northern Germany, and, moving very slowly following the upper drift, give great amounts of rain in Denmark and southern Sweden. This type of discontinuity is often very intricate and extremely hard to trace on the map, often lacking a marked resemblance to the life forms described above. The pressure field often takes the form of a barometric valley or trough. The slow propagation of these "amoeba" cyclones and the strong convergence of winds make them one of the strongest rain producers in southern Sweden. The same is the case when an originally real polar front is retarded in its movement or becomes stationary.

It may be pointed out that the average duration of each wave in a family according to the statistics of the first 140 days at the beginning of 1921, is 6.5 days for Scandinavia in good accordance with the period of Defant for average precipitation periods found for the Northern Hemisphere. The existence of a periodicity is also known for the Southern Hemisphere. Quite probably further details could be determined from a study of the phenomena of the "southerly burster" of Australia and the "pampero" of Argentina, both typical cold-front phenomena.

The step to tropical cyclone is natural. Professor Bjerknes[16] has advanced the theory that they have their origin in the "sliding surface" of the Trades.[17] According to H. U. Sverdrup[18] the general variations in the features of this surface account for the various phenomena in certain parts of the tropics and their frequent appearance in other parts.

NORWEGIAN WEATHER SERVICE: FORECASTING BY BJERKNES THEORY.

The Norwegian Weather Service is directed from three forecast centers, Christiania, Tromso, and Bergen. Bergen ranks second to Christiania in population, and has really a more important forecast division—that along the western coast, divided into 30 districts, north to a certain point where Tromso district begins, fishing being the prin-

[16] V. Bjerknes, On the Dynamics of the Circular Vortex with Applications to the Atmosphere and Atmospheric Vortex and Wave Motions. Christiania, 1921, *Geofysiske Publikationer*, Vol. II, No. 4, p. 83.

[17] This is referred to in the summary, MONTHLY WEATHER REVIEW, March, 1921, of an article by C. E. P. Brooks and H. W. Braby as the "mobile center of action" under the clash of Trades in the Pacific.

[18] H. U. Sverdrup, Der Nordatlantische Passat, *Veröffentlichungen des Geophysikalischen Instituts der Universität Leipzig*, II, Ser., 1917.

cipal Norwegian industry, both winter and summer. Christiania forecasts for the few, yet very important, agricultural districts to the south.

Weather forecasting in Norway according to the Bjerknes methods dates from the summer of 1918, when the number of observing stations was increased from 8 to 90,[19] an essential step to the discovery and identity of the lines of convergence with full accuracy. The ideal situation being that a complete picture of the state of the atmosphere should be represented, even the increase of stations to 90 was but a modest approach to the requirement that distances between stations be suitable as space differentials under any conditions.

There are at least five types of forecasts sent from the centers of the Norwegian Weather Service. First, the forecast of general conditions sent to the various small districts, especially precipitation forecasts in summer for agricultural interests; in autumn the storm warning forecasts for the shipping and fishing interests. Each day the pilot of the passenger and mail aeroplane from Bergen, Haugesaud, and Stavanger receives information of present conditions along the route, including observation of wind, direction and force, from different heights, as obtained from pilot-balloon observations, and, in addition, short-range forecasts.

The fourth type are those sent to the newspapers of the important towns of the districts; these really come under the first type, for they are usually modifications of the same, containing also descriptions of the general weather conditions. Lastly, in winter, come the snowstorm warnings for the mountains along the Bergen-Christiania Railroad.

A weather chart is prepared three times daily, at 8 a. m., at 2 p. m., and at 7 p. m. Forecasting in general is carried on for the most part along the usual meteorological lines, using the principal meteorological elements, wind, precipitation, humidity, and temperature, forecasts for visibility being made in special cases.

The problem of forcasting naturally presents itself in two alternative forms. It can be dealt with in two ways, either the polar front waves in any stage of the cyclonic life cycle as well as other marked secondary discontinuities, or following the two air masses, polar and tropical. In tropical air high temperatures and hazy or foggy weather are to be expected according to the origin of the air masses and the tendency to the formation of drizzle or the slightest forms of precipitation. Even very slight showers of rain may occur under the circumstances described above. Brilliant weather may be expected where the polar front keeps far from the forecasting district, either far south in the tropical highs so that Norway lies in cold polar air, or to the north, far enough so that the station is farther south than the area of poor visibility. Often in southern Norway in the spring this is true, when the center of the so-called Azores high may be found in southern Ireland or even farther northeastward. High winds are rather rare in this case, although they may also be found in tropical air when a decided frontal wave sweeps the territory.

In polar air a different type of weather conditions is to be found according to the time that has elapsed since the air masses left the polar regions. If the forecasting district is swept by the nearly stationary northerly winds of a recent great cold outbreak, then the temperatures are naturally low and visibility is very good. The cloud forms are of the cumulus type and give rise to showers in places where the topography is favorable. Fog never occurs in this situation; killing frosts are not infrequent in summer time. The winds are generally gusty or squally, often reaching gale force, marking the advance of the cold polar air.

If some time has elapsed since the polar air left the northern regions the districts covered by it have, in general, an intensified anticyclonic type of weather, no precipitation but with morning or night fogs due to radiation. As a rule, the force of the wind is low. With such conditions in the north, this is the ideal situation for the formation of secondary fronts toward the south. The summer thundershower of central Europe is a manifestation of the condition.

In the situation mentioned above, local conditions influence weather to a great extent, especially the flat summer types, when the weather is wholly local. Eastern Norway and great parts of Sweden in summer are dotted with local centers of shower generation, when moist air has been carried in to them by the sea breezes or more general winds. These, according to J. Bjerknes and H. Solberg[20] are situated on the slopes of mountain blocks or free peaks, where the release of the latent energy of the moist air takes place most readily. The very puzzling formation of the local shower in the mountainous districts of Norway is organically connected with and explained by Bjerknes's theory. The forecasting work for the eastern part of Norway is mainly "shower forecasting," especially in summer. This involves in a high degree the study of the meteorological elements with regard to local and topographical conditions. One of the most important factors used in the forecasting of summer showers is absolute humidity.

If the polar front passes over the forecasting district, the weather type is cyclonic. This does not alone imply the sequence of the weather of a full-grown cyclone, as described in J. Bjerknes's first paper, but also the later remarkably different stages which occur in the life cycle.

Strong increases in temperature are naturally bound to occur with the advance of a well-developed warm sector. If the cyclonic wave is secluded, the warm sector at the surface of the earth may have very little contrast to the surrounding polar air masses. Frequently the secluded wave gives no rise of temperature in the bottom layers of the atmosphere, but rather often a well-marked fall, as the passage of the front marks an inflow of originally polar air.

Specific rain areas are set out along the polar front following the line, one preceding the warm front, one following at the rear of the cold. The first is broadest, reaching 200 to 400 kilometers, while the latter is very narrow, often no more than 10 kilometers. It is always kept in mind that when one is using rain areas to fix the position of the polar front orographical conditions play an important part in the formation and distribution of rain.

Precipitation in the typical cases of younger cyclones is first the warm-front rain followed by the narrower cold-front stripe after an interval. In a "seclusia" this is also the case, although the weather chart shows less distinction between the two phenomena. The "seclusia" has one rain area or in its last state of degeneration only a cloud area. The last wave of a series is the more stormy, due to the squally nature of the cold outbreak.

[19] Figure 1, page 120, V. Bjerknes, "Structure of the Atmosphere when Rain is Falling," *Quarterly Journal of the Royal Meteorological Society*, Volume XLVI, Number 194, April, 1920.

[20] Meteorological Conditions for the Formation of Rain: J. Bjerknes and H. Solberg. *Geophysical Publications*, Vol. III, No. 3, Geofysiske Kommission, Kristiania, 1921.

The visibility, according to the origin of the air masses, changes with the passage of the two fronts. It is in fact one of the main characteristics of the different air masses. In the case of a dying or a dead cyclone it may happen that the polar air in following the degenerated front has been polluted in its passage over England and northern France before reaching Norway. Fog often occurs either as radiation fog in the high-pressure wedges between the moving cyclones, or as wet fog in the warm sector, usually immediately after the passage of a well-marked warm front, the sliding surface of which cuts the earth or, less commonly, in the outer diffuse parts, for example, in the occluded part of a dying wave or along the tail of such a wave, the cloud shield cutting the earth's surface in both cases.

In addition to these general conditions Scandinavian forecasters are well aware of special conditions and take them into account in forecasting. The polar front may be halted by the mountain ridge between the western and eastern parts of southern Norway, or between Norway and Sweden in the northern part. The cloud masses may cross the summit of the mountain ranges and extend beyond as alto-stratus. The cross-section of the channel of warm air between the fronts is diminished by the pressure at the sliding surface and the wind forces consequently increase. The forecast "southerly gale with rain" is issued when a cyclonic wave advances to the western coast of Norway. The forced rise of air which takes place along the sliding surface of the warm front is considerably increased and veritable deluges of rain are sometimes experienced at Bergen in these situations. Naturally great amounts of precipitation occur when a raining front is retarded or becomes stationary. Orographical conditions may retard part of the front while the rest of it may continue. This may even lead to the regeneration of the cyclone on the flanks of the retarding mountain range. This is an especially frequent occurrence in winter in Scandinavia.

Cold fronts as well as warm fronts may be halted against the mountain ranges. When the winds blowing with a mountain wall to the right of them in the Northern Hemisphere the deflecting force of the earth's rotation causes an increased gradient there and the wind force is consequently increased. This is such an important phenomenon in Norway that it is often the cause of special warnings for storms.

The most frequent discontinuity is that between temperatures of stations lying on the two sides of the polar front. These differences in winter are usually very marked, the summer conditions, on the other hand, reducing them to a minimum, the discontinuity at the surface of the earth often entirely disappearing through conditions of radiation, cloudiness, precipitation, and different effects from the distribution of land and water. The movement of the line may often be followed only by changes of temperature at stations passed by the line.

In the vicinity of the low, the line of demarcation is usually followed by trough lines in the field of pressure. These can best be used when a close network of stations is used, for sometimes only the irregularities in wind motion indicate the presence of these trough lines. It may happen that both are missing when the movement of the front is very slow.

In all the reports received from stations for the forecast charts barometric tendencies are carefully transmitted, these being considered the best criteria for placing the line, three-hour changes being recorded. Before the steering line passes pressure drops rapidly, as the passage the fall is suddenly checked, the barograph trace becoming nearly horizontal. In front of the squall line there is usually a slight dip in the pressure record with a sudden rise at the passage of the line.

* * * * *

The ultimate ideal of the Bergen Weather Bureau is to issue detailed forecasts arrived at by mathematical calculations of the movements of the polar front. Most important is the velocity of propagation, and the prediction of position. In the computations due regard must be taken of local controls, acceleration, and retardation, which complicate the problem immensely. Such calculation of the probable movement of the front is part of the daily forecasting work, approximation fixing the amount of retardation due to orographical obstacles. This is determined in part by comparing the actual wind velocities and the velocities indicated by the gradient.

APPLICATION OF THE BJERKNES THEORY TO THE SYNOPTIC CHARTS OF THE UNITED STATES WEATHER BUREAU.

Probably the first instance of an application in United States of methods of forecasting as developed at the "Vaervarslingen paa Vestlandet" was the discussion by C. L. Meisinger [21] and his series of charts showing streamlines giving the direction of the winds at the time of observation. He states, "This method has been devised by Bjerknes and used by him in his studies in forecasting in Norway and other parts of the world." Meisinger's charts also show the probable path of the wind of southerly component after it has left the ground at the wind-shift line. This article was one of a series in a study of the precipitation of sleet and the formation of glaze.

In partial explanation and to draw attention to the performance of the great cyclone of mid-February, 1919,[22] Meisinger made a second application of the Bjerknes theory and includes in his article eight remarkable illustions of the lines of the cyclone in question.

H. H. Clayton discusses an application of certain relations of wind to the gradient used while he was forecasting at Boston, Mass., from 1898 to 1903.[23] There may be thus a certain priority to Professor Bjerknes and Mr. Sandström, though Clayton's investigations were from a standpoint of practical forecasting without any attempt to discover the dynamic connections. His results were originally published in a short article in the MONTHLY WEATHER REVIEW, February, 1916, **44**: 80–81. Mr. Fox and Mr. Clayton seemed assured that if they could obtain telephonic reports of the time of beginning of rain in western and southern New England they could predict approximately the time of beginning in Boston. The plan was never put in operation, but Mr. Clayton states it needs only the energetic action of a sufficiently powerful organization to insure success.

Probably the first practical use in this country was that made by C. G. Andrus, observer, at Charleston, S. C., in September and October, 1920. At that time he applied Bjerknes' lines of convergence to the development of secondary lows on the ocassion of the International Balloon Races.[24] The main result of his work was an answer to the question, "Will a secondary unit of low pressure develop in the trough?" The conclusions reached were based on wind flow and temperature data. A squall-line, as long as it exhibits the well-known properties, may be considered a normal squall-line. Imme-

[21] MO. WEATHER REV., February, 1920, 48: 73–80 "Precipitation of sleet and formation of glaze in Eastern United States, January, 1920."
[22] MO. WEATHER REV., October, 1920, 48: 582–586.
[23] MO. WEATHER REV., February, 1920, 48: 83–84.
[24] MO. WEATHER REV., January, 1921, 49: 11–12. C. G. Andrus, "Application of Bjerknes's Lines to the Development of Secondary Lows.

diately a manifestation or tendency to manifest properties of the steering surface develops, the observer must be on the watch for the formation of a secondary. The first indications may be followed by a persisting tendency, and the secondary depression form, to remain, it may be, but a temporary one, yet the center of future developments. This seems to be a very frequent situation, not alone in the Mississippi Valley to which Andrus referred, but even more especially true of the Plateau Region to the southwest, as will be seen later.

A number of sporadic attempts to trace the lines on the Washington charts have been made at the Bergen Institute, but with only enough success to assure the investigators, that the lines were there and could be traced and used for more exact and detailed forecasting, especially with the introduction of more detailed reports.

In the preliminary investigations on the extension of the line of discontinuity about the pole, the charts published by the Deutche Seewarte under the direction of Captain Hoffmeyer,[25] have been more successfully used in determining the position of the line on the American continent and over the northern Atlantic.

More intensive work on the Washington maps (the details to be outlined later in this report) has shown the placing of the lines to be more or less satisfactory. Diversity of topography from west to east complicates the problem enormously but not nearly as much as the inadequate data given on the charts. In the first place, with the single exception of the Washington, D. C., reports, barometer readings are given to the nearest even hundredth inch and pressure variation for the nearest even hundredth, for a 12-hour period, abnormal change. Likewise, the same is true for temperature, even Fahrenheit degree, with even degrees for the 24-hour change. These conditions practically exclude an exact determination of the position of the steering surface, or warm front. The position of squall-lines or cold fronts seems more easily determined.

Only the barest possible data for clouds is available on the charts,[26] that is the reports of clear, partly cloudy, and cloudy, excluding the very best criteria available to the forecaster in the Scandinavian countries, the rate, direction, etc., of the cirrus sheet and other important details concerning the cloud cover. There are no visibility reports available, while in Norway fog, haze, and visibility are all reported. Time of beginning and time of cessation of rain are so important in marking the advance of either warm or cold fronts that they likewise have a place in the code reports.

Professor Bjerknes in his article [27] on the improvement of weather forecasting referring especially to the United States, suggests as of first importance the change from 8 to 16, or even 32, directions of wind. To observe and report these directions accurately "will be an important step in making it possible to draw the true lines of flow." This suggested change is not as important as an increase in the number of stations. In 1918, in Norway, when the increase of stations from 8 to 90 took place it gave an ideal distribution of about 80 stations to an area 5° square, from 58° to 63° north latitude, from 5° to 10° east longitude. The 8 stations at the beginning was about the distribution now to be found, for example, in 75°–70° west longitude, 40°–45° north latitude, or the following 8 or 10 stations, Portland, Me., Nantucket, Block Island, Hartford, New York, Concord, Northfield, possibly Canton and Philadelphia. That distribution is typical for the eastern part of the United States and is immensely better than any representative western section, say the possible three stations in the same latitudes, between 120° and 125° west longitude, Eureka, Red Bluff, and Roseburg. If the average were 8 to a 5°-area, this would be a great stride toward the ideal network. Professor Bjerknes suggests the change from climatological stations to telegraphic,[28] and then the number would be in about the same proportion to area as is used in western Norway. This is an ultimate ideal and probably the increase and improvement in radio telegraphy will some day make it possible.

With these generalized reports the criteria for indentifying the polar front were modified to fit the situation, in the study of the charts for January, 1921, which were chosen as an illustration for the United States.

The weather chart for Jan. 1, 1921 (Chart A. L. B. I.)—The warm front can be traced from the center of the cyclone in a general NW.–SE. direction first by the area of converging winds and secondly, by the actual discontinuities in temperature. For example, on the 8 a. m. chart of January 1, the edge of the steering surface of the cyclone central over Lake Superior, roughly marked by converging winds, has an average rise of temperature from stations east of the line to those on the west in the warm sector of about 12°. The line lies between Parry Sound and Saugeen, marked by the converging winds, between Oswego and Buffalo, where the temperature difference is 14°, Pittsburgh and Harrisburg, with a difference of 16° and continuing in a south-southeasterly direction, probably joining the cold front of the low off the Grand Banks.

These same stations are marked by discontinuities in the 24-hour barometer change; Harrisburg has had an abnormal rise of 0.04 inch over the 24-hour period, while the fall at Pittsburgh amounted to 0.18. A general cloudiness is to be found in the vicinity of the line, with precipitation at the time of observation at Parry Sound, Sault Ste. Marie, and Saugeen; at Houghton, Marquette, and Escanaba, where the line has passed, the amounts of precipitation have been respectively 0.01 inch and 0.08 inch within the preceding 24-hour period.

Summarizing, then the criteria for the location of the warm front are as follows:

1. General area of wind convergence toward center of the low. Increase in velocities.
2. Temperature discontinuities with greatest rise in 24 hours at the rear of the line, showing the warm front has passed.
3. Most marked fall of barometer for abnormal 24-hour change, with the passage of the line.
4. Precipitation along the line with general area of cloudiness, together with accumulated amounts for the past 24 hours.

One must take all these factors into consideration along with topographical conditions, which latter can not be enumerated here in detail but will be apparent to a more experienced forecaster.

At the rear of the warm sector comes the squall line running from the cyclonic center south or southwest. Often there is but one squall-line which marks the position of the polar front, far more frequently, several will be found marking the southward extensions of cold air of the advancing cold front.

[25] V. Bjerknes: "Om Vaer-og Stormvarslinger og Veien til at forbedre dem." Figures 6–11, pages 6 and 7. (An address delivered by Prof. Bjerknes before the Trades Council, May 4, 1920, Bergen.)

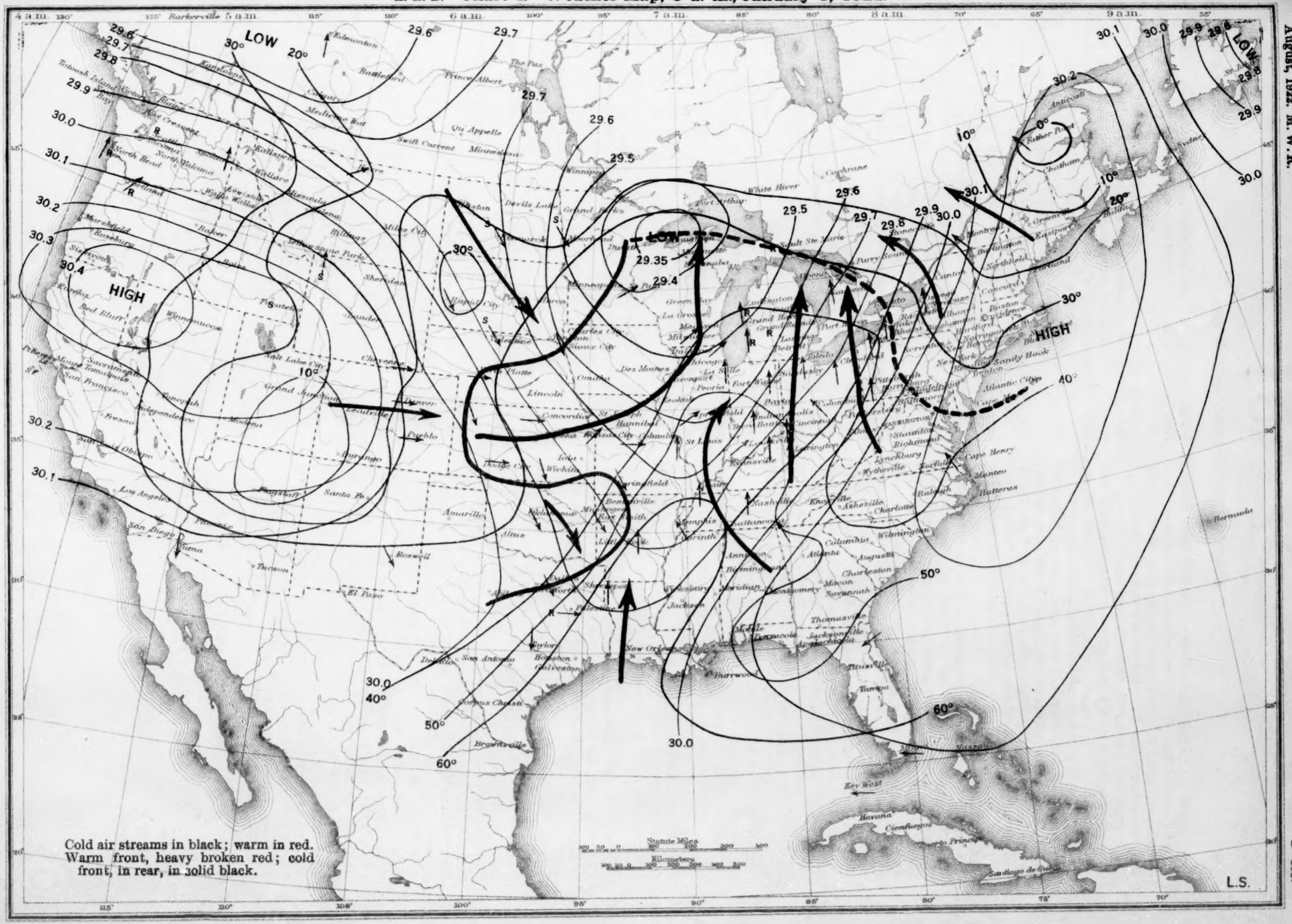
[26] The manuscript cloud chart prepared in the Weather Bureau Forecast Division, contains many details not shown on the printed daily weather map—Ed.

[27] V. Bjerknes: "Possible Improvements in Weather Forecasting." Monthly Weather Review, February, 1919, p. 99.

[28] This would involve about 4,500 stations.

A. L. B. Chart I. Weather Map, 8 a. m., January 1, 1921.

A. L. B. **Chart I. Weather Map, 8 a. m., January 1, 1921.**



August, 1922. M. W. R.

The position of the squall-line can be determined by the following criteria, the demonstration of which is given later:

1. Slight convergence of winds, which in the case of Washington charts is often obliterated by the use of only eight wind directions. Increased velocities.
2. Temperature discontinuities, with more marked fall at the stations where the line has passed.
3. Rising barometer with the passage of the line, determined from the 24-hour abnormal change.
4. Precipitation and cloudiness with the passage of the line, followed by clearing weather.

A common phenomenon with the passage of the squall surface in the warm season is the thundershower. This is not the local thunderstorm due to intense heating, but a typical cold-front phenomenon.

The low-pressure area mentioned above had not one but a fan of squall-lines, one line lying well along the eastern edge of the Mississippi Valley marked by strong wind convergence, strong temperature, and pressure discontinuities, the difference in temperature between Shreveport and Dallas being 22°, Little Rock and Fort Smith 20°, St. Louis and Columbia, Mo., 12°. The pressure increases rapidly in a series of steps to the north, as shown by the chart, and three at least, possibly five portions, of squall-lines can be identified; for example, that between Valentine and North Platte, the temperature difference being 4°, the fall 16° at Valentine compared with 6° at North Platte, the wind west at the latter station with the weather clear, while the former has a northwest wind accompanied by snow, the precipitation for the 24-hour period is already 0.02 inch.

These LOWS, together with a third central in British Columbia, are the last of a series begun in December. The one central over Lake Superior on the second has moved to the northeast to the south shore of Hudson Bay. The secondary squall lines are becoming very complicated, at least five secondaries appearing, one over the northern part of Texas being a well-developed LOW. By the third this secondary is giving heavy rain in the lower Mississippi Valley.

The map on the 4th at 8 a. m. is very complicated. The secondary mentioned has swept off to the Atlantic, while the LOW from the Pacific coast now lies north of the Great Lakes.

This series is terminated by an area of high pressure growing over the Winnepeg district, its cooling temperatures extending far south, so that the polar front lies off the Atlantic coast, south in or below the Gulf of Mexico, and then the warm front of the first of the new series carries it nearly due north along the borders of the Plateau district to the center of the low, which for purposes of discussion we will call B, the A series being considered as closed by the cold outbreak under observation.[29] * * *

DISCUSSION.

By ALFRED J. HENRY.

Chart A. L. B. I is the Daily Weather Map for January 1, 1921, redrawn from the map submitted by Miss Beck and altered very slightly as to the position of the polar front in the rear of the cyclone center. In redrawing the map I have used only wind directions for those stations at which the velocity was at least 10 miles per hour (4.5 m. p. s.). This was done in order to eliminate from consideration the records for stations at which light winds or calms prevailed.

The result of this omission is, first, the lines of flow as indicated by the long heavy arrows are based upon a smaller number of actual observations, and second, some directions that did not conform to the general lines of flow, probably due to light winds or calms have been eliminated from consideration.

That part of the polar front line figured by the heavy broken line in red is precisely as drawn by Miss Beck from a consideration of all the data, but the polar front in the rear of the cyclone center makes a sharp westward bend over Nebraska and an equally sharp return to the eastward over southern Kansas and Missouri. In thus drawing the line a number of northwest winds in the upper Mississippi Valley were ignored, since it seems probable that the shift of the wind to that direction must have occurred very close to the moment of observation. The temperature at the stations so ignored showed very little fall from the readings 24 hours previous.

The eastward inflection of the line over southern Kansas is illustrative of the manner in which a wedge of cold air rather frequently penetrates into the warmer air in the southern segment of a cylcone. From the forecasters point of view such a condition if carried on in an extensive scale means the extinguishment of the cyclone, but if only to a small extent, as here illustrated, it simply makes for a diminution in the amount of cooling experienced in the rear of the cylcone, since the colder air is manifestly soon shut off from the original supply.

The paucity of data of wind velocities west of the Rocky Mountains is strikingly illustrated by the chart in question. The remainder of the maps for January, 1921, considered by Miss Beck, have not been reproduced for want of space, and for other reasons. Many of the maps were unsatisfactory for the reasons so clearly stated by Miss Beck on a previous page.

It may not be amiss to here consider very briefly the suggestions of Professor Bjerknes in a previous article[29] that the number of telegraphic stations in the United States be increased by about 4,500. A little calculation will uncover the difficulties which lie in the way of carrying out the suggestion. The number of telegraphic stations at present is slightly more than 200. Under the most favorable conditions the data from these stations can be charted in 35 minutes and, allowing 15 minutes additional for generalizing the data, the forecaster is able to begin issuing forecasts within an hour from the time of observation. If the number of telegraphic stations should be increased upward of twenty-fold it would be physically impossible to chart and generalize the data within a reasonable time after the observing hour, even if the present district forecast centers, of which there are 5, should utilize reports from only such additional stations as would lie within their respective geographic districts.

[29] The remainder of the article takes up in detail the discussion of the groups of cyclones that crossed the United States in January, 1921. Space does not permit the reproduction of the series of maps, but the originals have been filed in the Weather Bureau library and are available to students and others who may wish to consult them. —Ed.

[29] See footnote 27.

J. BJERKNES AND H. SOLBERG ON METEOROLOGICAL CONDITIONS FOR THE FORMATION OF RAIN.[1]

By ALFRED J. HENRY.

[Weather Bureau, Washington, D. C., August 15, 1922.]

Force of circumstances during the Great War compelled Norwegian meteorologists to depart from the beaten path in weather forecasting and to adapt themselves to the use of such simple elemental data as could be obtained easily without expensive instrumental equipment and trained meteorological observers. On the basis of numerous wind observations, lines of flow were drawn, and largely from this simple beginning grew a series of studies of atmospheric movements that have yielded results of much importance to students of the forecast problem.

The authors have classified all rain occurring in Norway according to the mode of its formation and have illustrated the various types by charts and descriptive text. They fully recognize that the predominating influence in the formation of rain is the ascent and cooling of the air, hence their first inquiry concerns the conditions which develop and sustain ascending motions.

A comparison between the results obtained in Norway with the experience of forecasters in the United States is difficult by reason of the geographical position of the former and its exposure to the Atlantic Ocean on the west in the direct path of cyclonic storms which move in from the vicinity of Iceland.

That part of North America which corresponds in latitude to Norway extends from about Juneau, Alaska, northward to Point Barrow, the most northerly point of Alaska. Only a narrow strip of the coast in the latitude of Juneau (58° 18′) has any physical resemblance to the Norwegian coast. The meteorology of the coastal strip is fairly well known and in many particulars bears some resemblance to that of the southern Norwegian coast, but owing to the decided difference in the direction of the trend of the coast of Alaska as compared with Norway, the meteorological conditions which obtain over the greater part of the two regions are not similar.

Orographic rain.—The mountains of Norway trend almost parallel with the direction of the coast line, whence it follows that oceanic winds must ascend as they pass inland; consequently the regions of greatest rainfall are on the western slopes facing the ocean. The height of the mountains is not great and indeed there does not seem to be any very direct relation between altitude and depth of precipitation.

Cyclones passing inland over Norway are, of course, associated with northwest winds in their rear. As these winds cross the coast line they become ascending winds, whence it must appear that a large proportion of the precipitation of Norway might also be classed as cyclonic rain, although the authors do not so class it. Familiarity with the detailed topography of the coast line and the hinterland enables them to point out relations which to one not so familiar with the surface relief of the country would find difficulty in explaining. It is pointed out that in the cases under discussion the heaviest rain occurred along a narrow strip about 30 kilometers back from the coast. This condition is the normal one in Norway, there being, however, more rain in the south than in the north.

The authors distinguish between pure orographic rain and rain that is deposited by a westerly current, which bears rain even over the sea entirely independent of orographic influences. They say, speaking of orographic rain in western Norway:

> Pure orographic rain in western Norway seldom exceeds 5 mm. in 24 hours even in the zone of maximum amounts. A westerly current containing showers over the sea may, however, in the same zone cause rain up to 30 mm. in 24 hours.

This is explained as follows: Shower-bearing winds are retarded as they pass inland and move with smaller velocity or even stop. The amount of precipitation from each shower will, of course, be greater the slower the movement, and thus the showers may add to the orographic precipitation more than they can give alone over the sea, provided that they have not meanwhile diminished in intensity. The region of maximum amounts of precipitation is a place where showers for topographical reasons are forced to move slowly without a decrease in intensity.

Stable and unstable air currents will behave differently when they cross a mountain range. Air masses of a stable current being forced to ascend against the mountain will become colder and thus heavier than the surrounding air at the same level and will resist further vertical displacement. The air in unstable currents, on the other hand, will become lighter than the surrounding air as it ascends, and thus supplements the initial motion. Therefore stable air currents are more likely to pass around the mountain than to override it, and the amount of orographic rain will, of course, be greater in the latter than in the former.

Unstable currents, it is stated, are those which originate in cold regions and are later warmed on the underside. In all seasons northerly currents are most likely to become unstable since they bring air from colder to warmer parts of the earth. Unstable currents may, however, come from any direction, even the south; but they are the branches of originally cold currents following curved paths.

Air currents originating in warmer parts of the earth will be cooled from below as they reach colder regions and will therefore be stable. In such currents, however, the cooling of the lower layers by the ground may lead to the formation of fog, or even a slight drizzle.

Summarizing their studies as to orographic rains the authors conclude:

> Pure orographic rain, which necessarily forms as well in stable as in unstable currents, occurs only in connection with mountains at least 1,000 meters high. Showers due to instability may, in particular cases, add considerable amounts to that of the pure orographical rain and make even orographical rain possible in connection with smaller obstacles. The effects of orographical rain are strongly restricted by the tendency of all stable air currents to curve round the mountains horizontally.

The authors recognize the fact that the greater part of orographical rain will occur simultaneously with rainfall of other origin. The combined cyclonic and orographical rain is much more abundant than the simple orographical rain of homogeneous currents.

The conditions which give rise to ascending currents in the free air are discussed at much length and in great detail for which the reader must consult the original

[1] *Geofysiske Publikationer*, Vol. II, No. 3, Kristiana, 1921.

contribution. Three different types are distinguished as shown in figure 1 below.

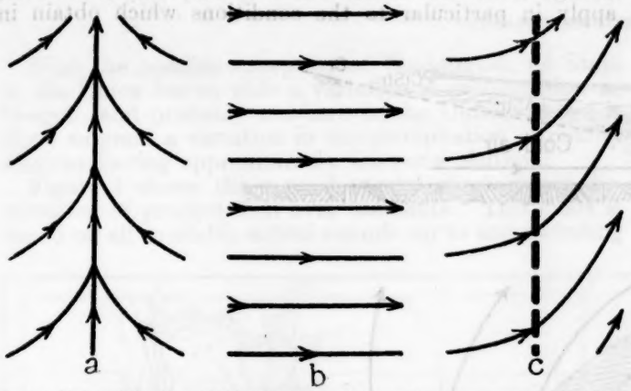


FIG. 1.—[Original No. 5]; *a*. Field of flow in a stationary line of convergence; *b*. Additional field of translation; *c*. Resulting field of flow in a moving line of convergence.

It is the experience of Norwegian meteorologists that the regions of strong convergence of the winds are arranged along narrow strips, or lanes corresponding to lines of convergence in the field of horizontal motion. The simplest form of a line of convergence is that shown in figure 1a. In this case lines of flow pass symmetrically from both sides toward a central line of flow. This type, it is remarked, is a rather special one and does not often occur in nature. A more general line of convergence is obtained when a vector field of constant translation (Fig. 1b) is added to the field of a symmetrical line of convergence (Fig. 1a) which results in a field of flow of the type represented by figure 1c. The former line of convergence is represented by the dotted line, which is no longer a line of flow but rather a line through the places having wind-shift at the moment to which the map in question refers. Thus it corresponds to a more or less accentuated trough-line in the field of pressure.

The new shape of the wind field implies, however, no change in the field of vertical motion. This field being constructed by aid of the equation of continuity will be just the same for figure 1a and figure 1c in both cases showing a narrow belt of rapidly ascending motion along the line of convergence, figure 1a and figure 1c, respectively. The ascending motion at the wind-shift line is much greater than that occurring in simple homogeneous currents without discontinuous changes of wind direction and velocity. Clayton [3] has pointed out the fact that a system of converging winds is indicative of precipitation but the application of the idea to forecasts of rainfall in the United States has not made much progress for various reasons, chiefly because lines of convergent flow are not clearly shown by reason of the distance between reporting stations.

The authors now consider cases of warm air displaced by a moving wedge of cold air, cold-front rain, and the conditions under which a moving wedge of cold air may produce orographical rain in connection with the topographic features of Norway.

The cold air may advance from the west in the rear of a V-shaped depression and also in many other types of pressure distribution.

[3] Clayton, H. Helm, Relation between rainfall and synoptic winds; MO. WEATHER REV. 44: 80-81.

Another condition under which air is made to ascend is that of a warm front advancing against a retreating wedge of cold air, such as would be involved in the advance of a cyclone into regions occupied by a retreating anticyclone. The thought here is centered upon the warm front of the cyclone as it advances into regions of colder air. The authors' conception of the phenomenon is illustrated in Figure 2 below.

In this figure the line of discontinuity is drawn through the cyclone without the deformation produced by the mountains of Norway, and the figure thus represents an idealized cyclone over perfectly flat ground. The shaded area indicates the region of precipitation at the moment of observation. It consists of the warm-front rain extending as a broad, curved zone in front of the tongue of warm air, and the much narrower band of cold-front rain in the rear. The upper part of Figure 2 represents a vertical section through the cyclone to the north of the center. The succession of the weather, reading from right to left, is also shown. Such a section cuts the rain area only once, corresponding, thus, to a single rainfall of duration according to the relative distance from the center.

The lower part of Figure 2 is a vertical section sketched through the cyclone to the south of the center. It gives, from right to left, the succession of weather to the south of the passing cyclone. First is the passage of typical warm-front rain preceded by an extensive shield of Ci., Ci-St., and A-St. clouds, then a rain-free, relatively warm, spell of weather during which the cloud shield of alto-cumulus appears, announcing the approaching cold-front rain.

With regard to the height above the surface that the bounding surface of a cyclone may reach the authors place it at about 9 km., as shown in the lower part of figure 2. In explanation they say:

> All the clouds preceding the warm-front rain, cirro-stratus, alto-stratus, and mammato-stratus, are typical sheet clouds, and their mutual connection makes it probable that they belong to the same inclining boundary surface which can be observed in the lower atmosphere. Even the tufted cirrus is a sign for the existence of a surface of discontinuity at that height. The tufted cirrus must consist of ice crystals falling from the tufts through a well-defined surface of discontinuity into a layer with different velocity from that of the tufts.
>
> The ice crystals will there form a long tail in the direction of the vectorial difference of winds above and below the surface of discontinuity.
>
> As tufted cirrus always move nearly in their own longitudinal direction, the tufts being directed forward, it may be concluded that the velocity up above the surface of discontinuity has stronger component forward than the velocity below. We thus get a picture of a strong upper current penetrating forward and probably a little upward in front of the continuous cyclonic cloud masses. It is not improbable that we here observe the uppermost part of the warm current above the warm-front surface. * * *. These questions, however, must be more closely examined before definite opinions can be stated.

The conditions favorable to the development of local showers are discussed with particular reference to the topographic control exerted by the mountains of Norway. Typical summer rains are said to develop first in the mountains lying within reach of the sea breeze of the first several days. It should be said that the sea breeze penetrates inland a certain distance on the first day and retires toward the coast at night; the second day it has some of the sea air in front of it which was brought in the first day and forces this air to ascend. Conditions are therefore more favorable to the development of local showers the second day than the first and still more favorable on the third, and so on. As the velocity of the

sea breeze is small the regions farthest from the coast will be reached after several days. But if the calm-weather type persists the whole country will, sooner or later, be covered by air which has been previously over the sea. When that stage is reached the great moisture content permits local showers to develop over the whole country wherever strong convective currents are rising. This is the type of continental summer rains and it may persist for weeks at a time.

Numerous charts are presented illustrating the development of showery weather in summer and the gradual change from showers to fair weather; these, however, apply in particular to the conditions which obtain in Norway. The following conclusion is of considerable interest to forecasters in the United States:

The properties of the air in respect to stability and content of moisture are more important factors for the occurrence of local showers than the general distribution of pressure.

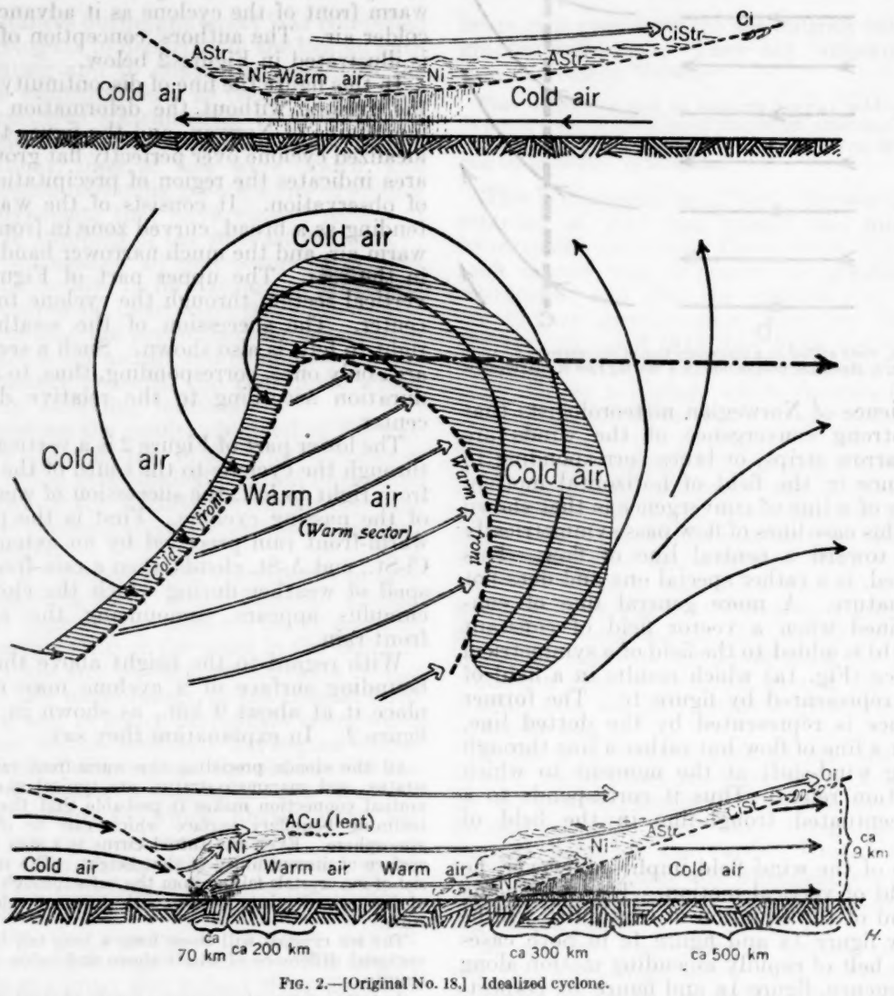


FIG. 2.—[Original No. 18.] Idealized cyclone.

PRECIPITATION IN OREGON.

EDWARD LANSING WELLS, Meteorologist.

[Weather Bureau, Portland, Oreg., July 22, 1922.]

With the possible exception of Washington, no State in the Union has so wide a variation in precipitation as Oregon, and probably nowhere in the United States is there so great a variation in the precipitation of nearby stations having approximately the same altitude.

Figure 1 shows the normal annual geographical distribution of precipitation over the State. This chart is based on all available actual records up to and including 1920. The records are for varying periods, and probably do not represent a true normal in any instance. Longer records and a much larger number of them are necessary for the preparation of a chart showing the true normal precipitation, which, however, is approximately as shown.

The range is from 8 inches at Umatilla, on the Columbia River, in Umatilla County, to 132 inches at Glenora, on the west slope of the Coast Range, in Tillamook County. Mr. E. C. La Rue, of the United States Geological Survey, prepared a rainfall chart of western Oregon several years ago, on which a small area near Glenora was credited with more than 200 inches, and a part of the west slope of Mount Hood was credited with more than 140 inches annually, but these amounts were estimated, from stream flow, and by comparison with records at nearby stations.

The three principal factors in the distribution of rainfall, viz, altitude, distance from the sea, and exposure to rain-bearing winds, are all plainly evident in Oregon, but are so complex in their action as to present some apparent anomalies, and to make it very difficult to estimate the rainfall of any locality from records made in another locality.

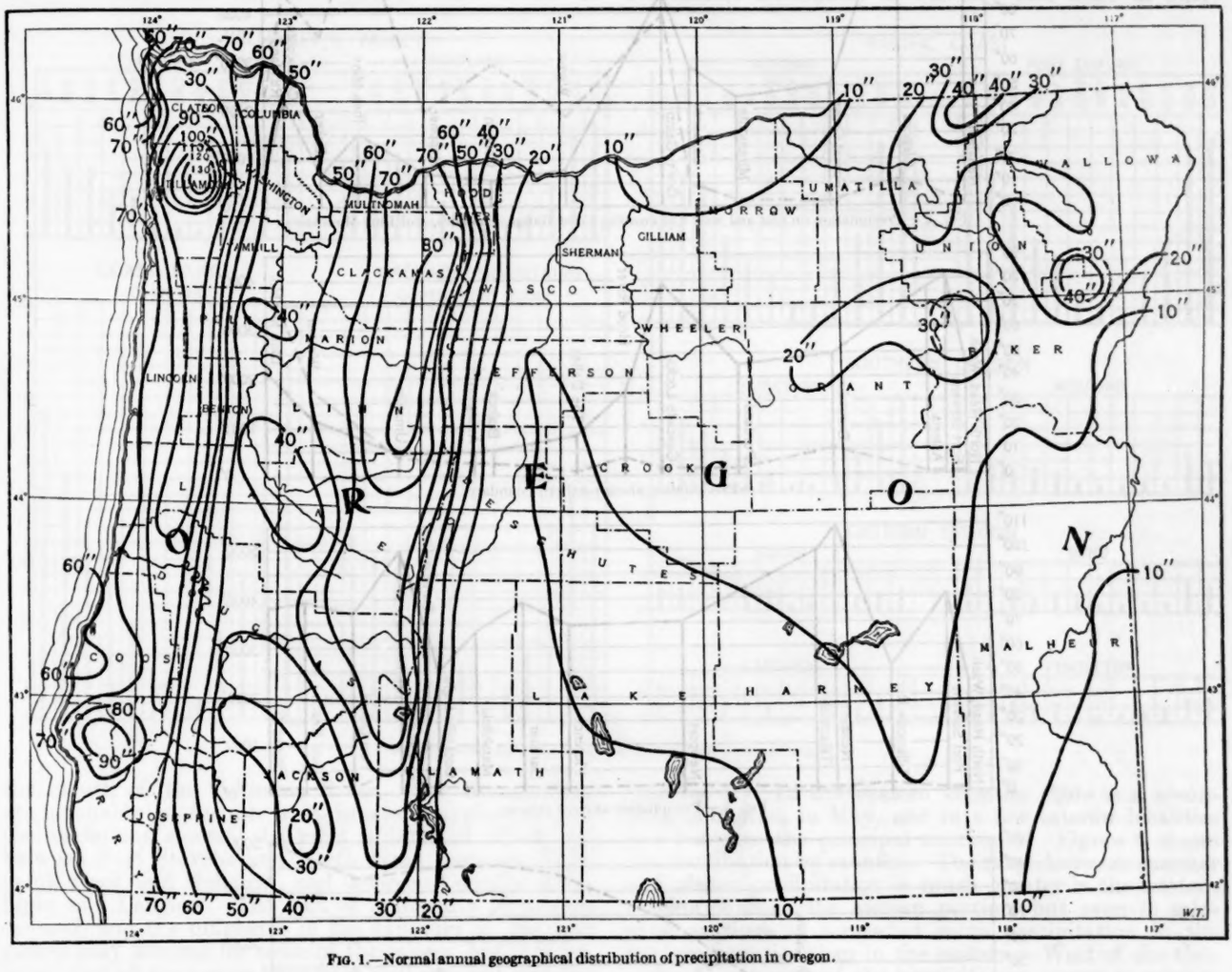


FIG. 1.—Normal annual geographical distribution of precipitation in Oregon.

In a general way, the rainfall increases rapidly with altitude on the west slope of the Coast Range, decreases from the summit of the Coast Range to the valleys of the Willamette, Umpqua, and Rogue Rivers, increases with altitude on the west slope of the Cascades, decreases abruptly on the east slope of the Cascades, and is fairly uniform over the high eastern plateau and very unevenly distributed in the Blue Mountains and adjacent territory. This is roughly shown in Figure 2, in which precipitation and altitude are compared along an east and west line

extending from Nehalem, in Tillamook County, to Richland, in Baker County. This line shows a relation between elevation and precipitation that, while not constant, is still unmistakable. It shows also the effect of nearness to the ocean and of exposure to the moist southwesterly winds.

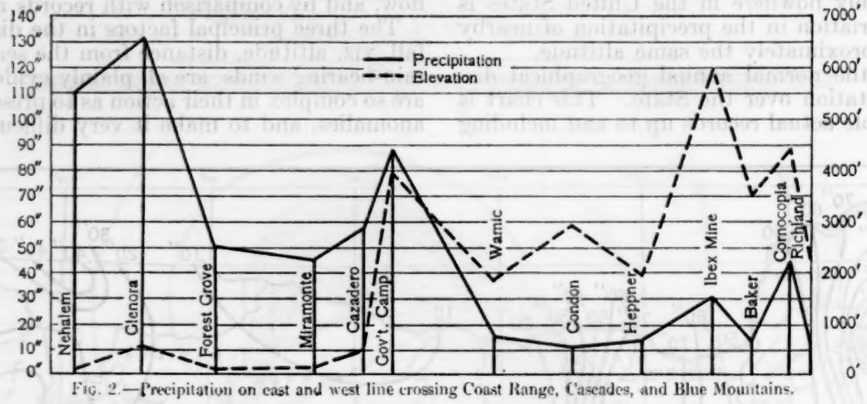


FIG. 2.—Precipitation on east and west line crossing Coast Range, Cascades, and Blue Mountains.

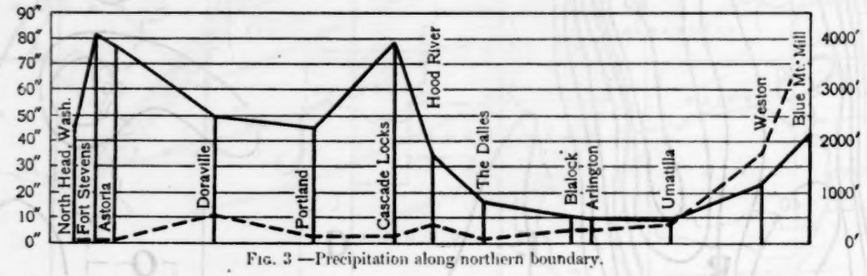


FIG. 3 —Precipitation along northern boundary.

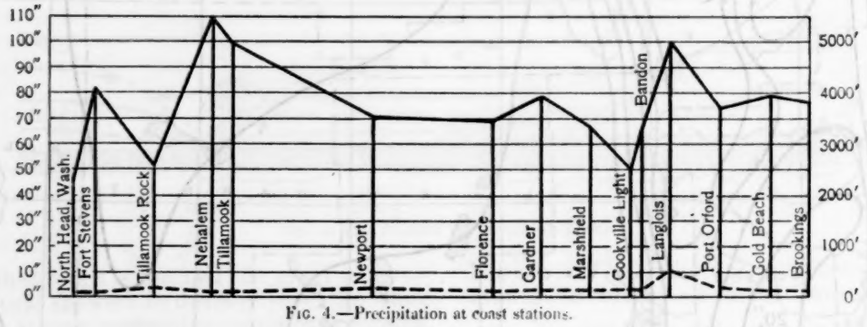


FIG. 4.—Precipitation at coast stations.

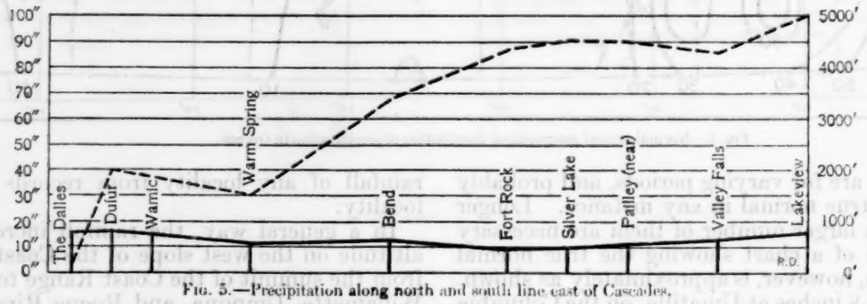


FIG. 5.—Precipitation along north and south line east of Cascades.

FIGS. 2-5.—Topographic and rainfall profiles in various parts of Oregon.

However, Figure 3, which shows the distribution along the northern boundary, which, for most of the distance, is the Columbia River, presents much the same type of precipitation distribution, without material difference in altitude except east of Umatilla, where the boundary leaves the Columbia River. In this figure the line begins at North Head, Wash., which is more nearly typical of the exposed coast stations than is Fort Stevens or Astoria. Cascade Locks has 75 per cent more precipitation than Portland, although it is at about the same altitude, only a few feet above sea level and is 43 miles farther from the ocean. It is, however, in the Columbia River Gorge, with mountains on either side, and the heavy precipitation is due to the influence of these mountains, but this does not explain why Cascade Locks has more precipitation than Welches, which is nearby but at an

elevation of 1,435 feet. Hood River, 20 miles east of Cascade Locks, has less than half as much rainfall as Cascade Locks; The Dalles, 21 miles beyond Hood River, has about half as much as Hood River; and at Blalock, 54 miles farther inland, the precipitation is but little more than half that at The Dalles. The character of vegetation between Cascade Locks and Blalock shows very clearly the marked difference in rainfall.

An interesting feature is the wide range in precipitation along the coast, as shown in Figure 4. It is commonly stated that the rainfall along the Pacific coast of the United States increases from south to north. This statement is not borne out by the figure, for the Curry County coast has more rainfall than occurs at Bandon are very freely exposed, while Marshfield is sheltered.

Figure 5 shows the distribution along a line drawn roughly from north to south east of the Cascade Mountains, extending from The Dalles to Lakeview. Here, while the altitude ranges from near sea level to 5,000 feet, the extreme range in precipitation is less than 8 inches. The Dalles at the lowest point has the most precipitation, and Fremont, with an elevation of 4,300 feet, has the least. The sheltering effect of the Cascade Mountains, and the increased distance from the normal track of low pressure areas, offset the effect of increased altitude.

Over most of the State the precipitation is greatest in November, December, or January and least in July.

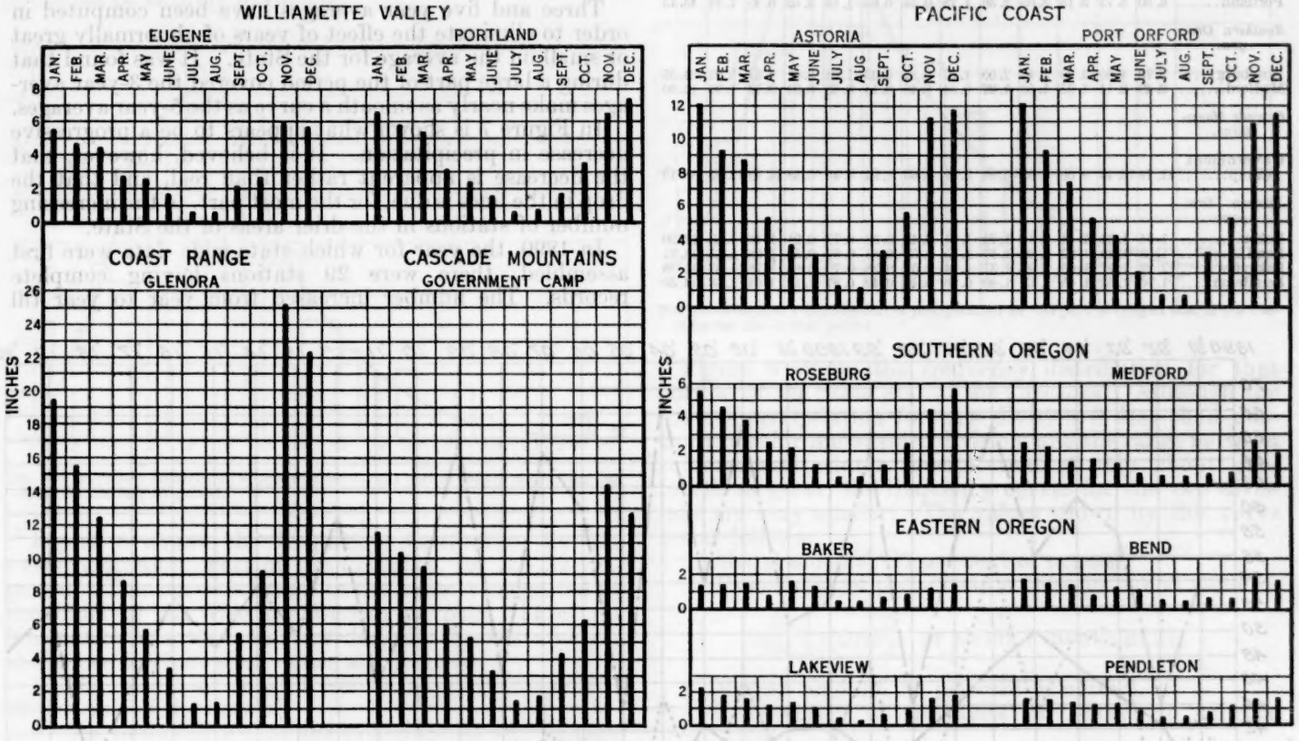


FIG. 6.—Mean monthly precipitation in various parts of Oregon.

the mouth of the Columbia River. Not enough data are available to furnish a satisfactory explanation of the variations shown, the most notable of which are between Fort Stevens and North Head, between Tillamook Rock and Nehalem, and between Coquille River Light and Langlois. The lack of uniformity in periods covered, and the difference in the exposure of the rain gauges may account for some of the ranges, but it is believed that all the gauges have been well exposed, and the records cover periods long enough to mask most of the fluctuations occurring from year to year. The stations most freely exposed to the sea, namely North Head, Tillamook Rock, and Coquille River Light, have the least rainfall, while Nehalem and Langlois, which are back a short distance from the beach line, have very heavy rainfall. However, Port Orford, Gold Beach, and (See fig. 6.) In the eastern counties there is a secondary maximum in May, and in a few interior localities this becomes the principal maximum. Figure 6 shows the distribution by months. The range between summer and winter precipitation is much greater in the western portion than in the eastern portion, but even in midsummer there is somewhat more precipitation in the western counties than in the eastern. West of the Cascades 44 per cent of the precipitation occurs in winter, 23 per cent in spring, 6 per cent in summer, and 27 per cent in fall. East of the Cascades 38 per cent occurs in winter, 25 per cent in spring, 10 per cent in summer, and 27 per cent in fall. In the former area the winter precipitation is more than seven times the summer precipitation, while in the latter the winter precipitation is less than four times the summer precipitation.

The numerical values on which Figure 6 is based are given in Table 1.

TABLE 1.—*Normal monthly precipitation, inches (selected stations).*

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Coast.													
Astoria	12.10	9.47	8.84	5.30	3.71	3.00	1.31	1.25	3.46	5.75	11.03	11.98	77.20
Port Orford	12.41	9.45	7.67	5.41	4.18	2.27	0.62	0.47	3.50	5.47	11.01	11.81	74.27
Coast Range.													
Glenora	19.59	15.80	12.56	8.96	5.92	3.60	1.29	1.34	5.75	9.30	25.15	22.33	131.99
Willamette Valley.													
Eugene	5.40	4.68	4.29	2.68	2.54	1.56	0.45	0.50	2.03	2.65	5.95	5.76	38.49
Portland	6.50	5.73	5.18	3.05	2.36	1.78	0.54	0.65	1.84	3.69	6.47	7.34	45.13
Southern Oregon.													
Roseburg	5.70	4.56	3.90	2.48	2.05	1.07	0.32	0.33	1.04	2.61	4.37	5.92	34.35
Medford	2.49	2.14	1.35	1.50	1.27	0.84	0.46	0.14	0.69	0.84	2.73	1.95	16.40
Cascade Mountains.													
Government Camp	11.79	10.46	9.60	6.02	5.24	3.39	1.65	1.92	4.40	6.38	14.43	12.85	88.13
Eastern Oregon.													
Baker	1.34	1.34	1.44	0.94	1.73	1.21	0.43	0.39	0.76	0.91	1.18	1.53	13.20
Bend	1.83	1.49	1.22	0.80	1.17	1.05	0.53	0.33	0.67	0.56	1.98	1.68	13.31
Lakeview	2.22	1.97	1.60	1.09	1.37	1.04	0.39	0.28	0.70	0.85	1.78	1.87	15.16
Pendleton	1.70	1.55	1.45	1.13	1.40	0.96	0.46	0.49	0.87	1.12	1.64	1.53	14.30

Figure 7 shows the sequence of annual precipitation from year to year in the eastern division, the western division, and the State as a whole. The curves are drawn for the average precipitation as published in the Oregon annual summary. The first impression given by this figure is that of a fairly regular periodicity, with a period of about three years. In no instance is there a continuous increase or decrease lasting more than two years. This supports a theory advanced several years ago by Mr. George N. Salisbury, of the Seattle Weather Bureau office. (MONTHLY WEATHER REVIEW, 1903, **31**: 229.) It is probable, however, that little practical use can be made of this periodicity for forecasting purposes, because the maxima or minima may be anywhere from two to four years apart.

Three and five year averages have been computed in order to eliminate the effect of years of abnormally great or small on the average for the State. It was found that during a large part of the period covered the 3-year averages make nearly as smooth a curve as the 5-year averages.

In Figure 7 is shown what appears to be a progressive decrease in precipitation. It is believed, however, that the decrease is apparent rather than real, and that the drop in the lines is due, for the most part, to the increasing number of stations in the drier areas of the State.

In 1890, the year for which state-wide data were first assembled, there were 29 stations having complete records. The number increased from year to year till

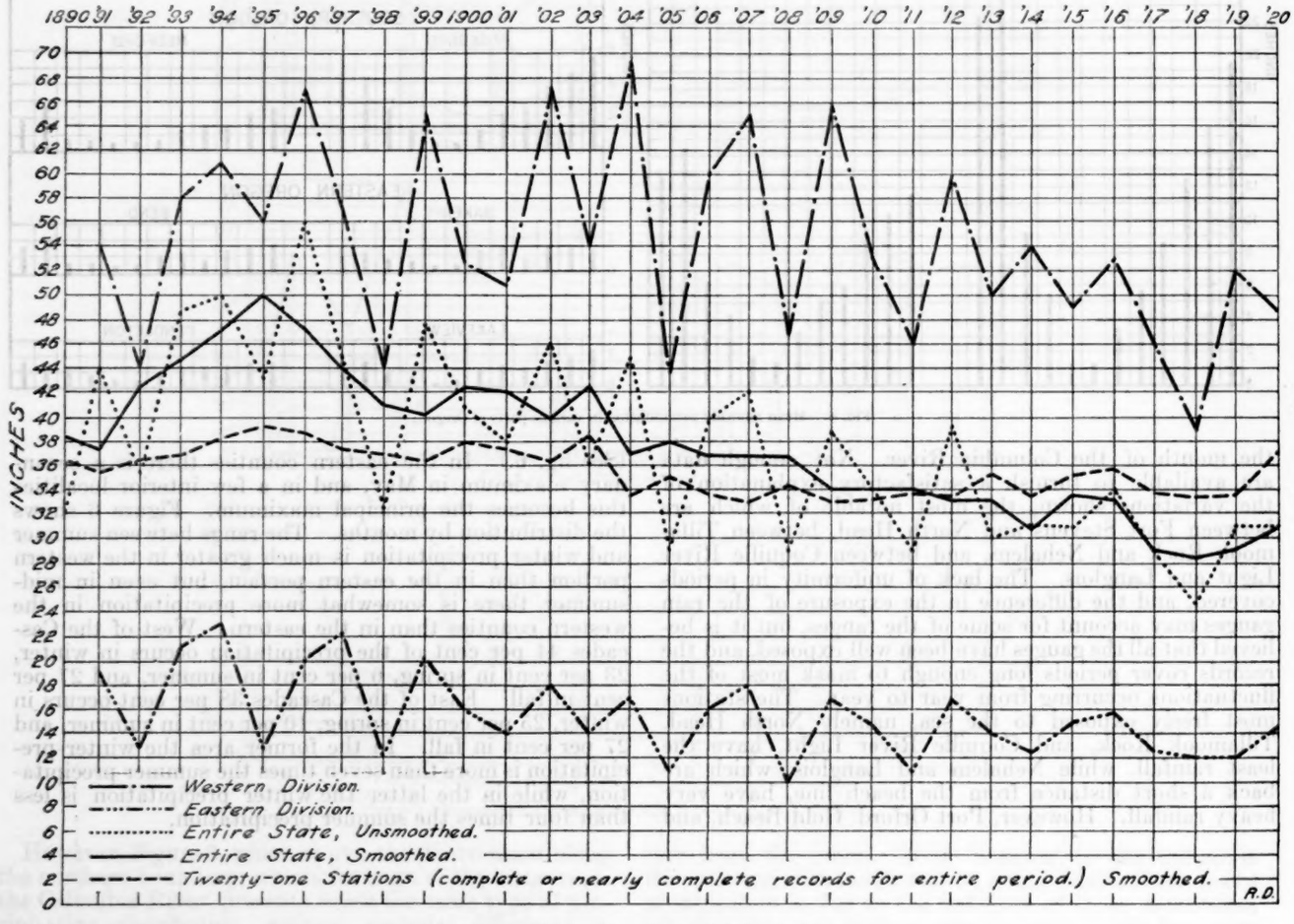

1890 '91 '92 '93 '94 '95 '96 '97 '98 '99 1900 '01 '02 '03 '04 '05 '06 '07 '08 '09 '10 '11 '12 '13 '14 '15 '16 '17 '18 '19 '20
INCHES
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70
Western Division.
Eastern Division.
Entire State, Unsmoothed.
Entire State, Smoothed.
Twenty-one Stations (complete or nearly complete records for entire period.) Smoothed.
R.D.

FIG. 7.—Thirty years' record of precipitation in Oregon.

1913, when there were 125 stations having complete records. By 1921 the number had fallen to 100. As the most rapid agricultural development in this period has been in the semiarid portions of the State, under irrigation and improved dry farming methods, it is natural that the greater number of new stations established should be in the drier regions.

In Figure 7 a smoothed curve of the annual precipitation, as published from year to year in the annual summary, is compared with a similar curve representing the annual precipitation at 21 stations having nearly or quite complete records for the 32-year period, 1890 to 1921, inclusive. The latter curve shows a slight downward tendency in the second decade, which is partially overcome later, and which, in a longer period, would doubtless be entirely overcome.

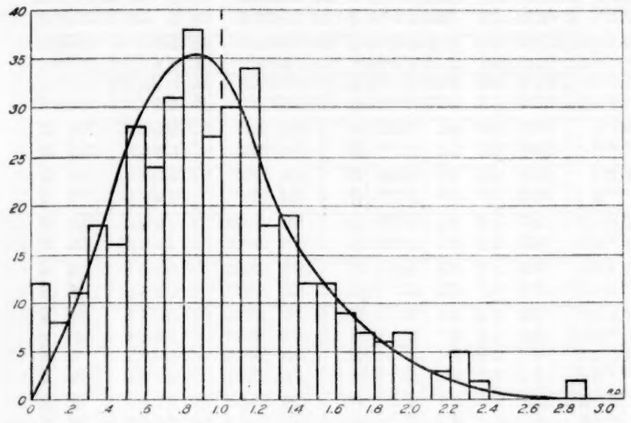


FIG. 8.—Frequency distribution of precipitation for the part of Oregon west of the Cascades for the 32-year period.

Figure 8 shows the frequency distribution for the western division, west of the Cascades, for the 32-year period. This curve is drawn in the manner suggested by the Chief of the Weather Bureau on page 121 of the MONTHLY WEATHER REVIEW for March, 1921. From this curve the following values are deduced:

1. The modal or most frequent monthly amount is 90 per cent of the normal.

2. The probability that the precipitation will be close to the modal amount, say between 0.875 and 0.925, is

$$\frac{35.5}{766.9}=0.04\frac{6}{10},\text{ or 1 month in 22.}$$

3. The median amount is also 90 per cent of the normal.

4. The probability of the monthly precipitation being close to the normal, say between 0.975 and 1.025, is

$$\frac{34.2}{766.9}=0.04\frac{1}{2},\text{ or 1 month in 22.}$$

13352—22——2

5. The probability of rainfall greater than the normal is

$$\frac{766.9-453.2}{766.9}=0.41.$$

6. The most probable amount greater than the normal is 130 per cent.

7. The most probable amount less than the normal is 67 per cent.

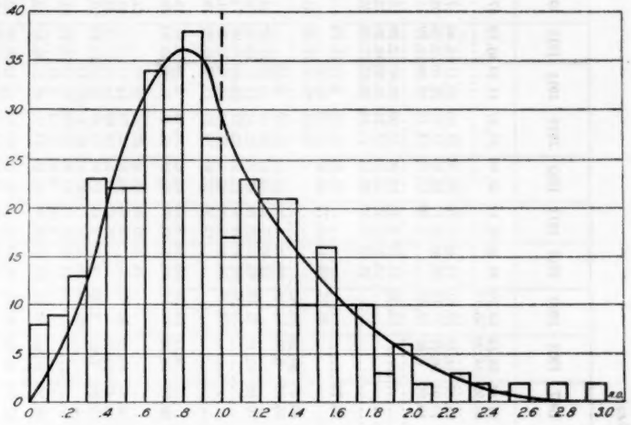


FIG. 9.—Frequency distribution of precipitation for the part of Oregon east of the Cascades for the 32-year period.

Figure 9 shows the frequency distribution for that portion of the State east of the Cascades. Although the normal precipitation for this division is less than one-third that for the western division, and the range between summer and winter precipitation is only about one-fourth as great, the frequency curves for the two divisions are very similar. The values shown by this curve are as follows:

1. Modal amount, 80 per cent of normal.

2. Probability of precipitation close to modal amount,

$$\frac{36.1}{760.8}=0.04\frac{3}{4},\text{ or about 1 month in 21.}$$

3. Median amount, 88 per cent of normal.

4. Probability of precipitation close to normal

$$\frac{28.8}{760.8}=0.03\frac{4}{5},\text{ or about 1 month in 30.}$$

5. Probability of rainfall greater than normal,

$$\frac{760.8-457.2}{760.8}=0.40.$$

6. Most probable amount greater than normal, 135 per cent.

7. Most probable amount less than normal, 66 per cent.

Table I gives the annual precipitation for most of the stations in the State having records for any considerable portion of the 32-year period under consideration.

TABLE I.—*Annual precipitation, Oregon (inches).*

Station.	County.	Elevation.	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921
Albany	Linn	212	40.02	53.39	37.93	46.07	49.86	47.48	57.15	50.19	36.22	46.99	38.88	38.89	52.94	33.65	49.41	30.19	40.72	44.44	28.54	43.70	38.30	34.11	46.68	35.37	44.24	40.12	47.74	39.50	34.31	52.85	38.59	44.59
Alpine	Benton	400	.....	.....	8.01	11.48	12.65	7.78	11.75	8.40	36.67	55.61	44.24	49.05	66.37	43.59	63.15	.....	48.08	56.92	34.20	55.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Arlington	Gilliam	400	.....	.....	15.36	24.22	22.28	13.99	24.25	17.72	5.33	10.11	9.89	12.96	11.16	8.46	9.38	9.08	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ashland	Jackson	1,963	20.26	23.74	70.01	91.68	88.84	70.75	94.82	85.06	15.57	19.54	21.09	18.21	22.60	21.25	25.11	11.99	24.25	28.87	14.58	27.61	17.82	18.78	26.26	21.90	20.11	18.46	17.47	19.06	21.15	20.24	19.26	20.56
Astoria	Clatsop	16	58.49	77.74	11.95	15.83	17.83	12.00	13.37	14.68	68.72	101.40	84.97	77.87	86.48	74.86	88.67	72.63	82.73	73.91	56.71	70.10	86.85	59.17	85.89	71.27	76.10	79.23	92.50	.....	.....	.....	80.90	93.69
Baker	Baker	3,471	12.50	18.23	66.52	93.58	103.97	100.63	62.83	51.05	8.52	15.11	13.84	10.64	12.80	10.57	12.34	12.25	13.56	10.90	8.61	13.55	.....	9.89	13.77	14.18	10.89	13.79	11.91	10.29	7.71	7.84	9.96	13.29
Bandon	Coos	55	58.78	78.11	.....	.....	.....	.....	.....	.....	50.27	70.74	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.50	11.37	8.35	12.96	13.99	10.83	12.56	13.39	9.44	12.06	11.23	10.71	13.07
Bear Creek	Crook	4,800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.20	11.32	18.80	17.74	12.66	19.26	22.20	12.74	10.71	13.42	19.35	16.76
Bear Valley	Grant	5,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.81	15.55	26.64	21.14	19.35	21.65	25.00	19.40	12.09	15.72	20.35	16.43
Beech Creek	Grant	5,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Bend	Deschutes	3,629	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	48.30	10.90	13.37	17.10	.....	10.42	25.75	.....	58.77	39.44	36.75	16.62	12.39	8.12	11.75	.....	8.80	10.27	11.07	11.27	12.99
Black Butte	Lane	1,200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	62.77	46.27	60.09	37.60	.....	.....	.....	.....	.....	.....	65.25	51.20	52.05	.....	.....	.....	.....	.....	.....	.....
Brookings	Curry	130	.....	.....	.....	.....	.....	.....	.....	.....	.....	73.41	56.40	63.41	90.12	69.49	96.74	43.23	70.79	80.40	53.29	95.62	.....	.....	.....	78.56	89.06	77.89	81.66	74.34	49.69	74.90	75.77	75.48
Buckhorn Farm	Josephine	1,300	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.66	10.44	18.12	15.57	8.01	14.08	12.32	6.18	13.64	13.82	9.65	.....	.....	.....	.....	8.00	11.16	10.66	.....
Burns	Harney	4,170	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	37.97	27.73	39.87	29.69	30.70	27.28	31.86	.....	.....	.....	.....	.....	37.96
Butte Falls	Jackson	2,550	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	75.13	85.81	60.10	87.79	72.51	73.73	78.32	78.10	85.79	67.73	83.94	84.32	89.73
Cascade Locks	Hood River	100	70.96	87.24	63.49	96.63	94.22	71.03	94.97	88.67	76.28	97.95	76.73	76.97	93.35	72.24	76.26	58.66	77.98	79.69	65.15	70.35	57.40	54.51	72.55	62.27	55.00	63.07	73.01	67.16	.....	77.12	72.02	73.00
Cascadia	Linn	1,050	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	66.11	54.41	49.09	59.33	52.33	50.15	57.48	61.04	63.91	46.97	63.77	.....	65.98
Cazadero	Clackamas	503	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.56	27.96	18.33	15.67	16.06	18.65	17.16	16.29	14.19	16.43	15.33
Chiloquin	Klamath	4,200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.11	13.21	10.19	8.22	15.42	13.14	8.39	13.41	15.72	13.38	9.40	12.74	14.30	17.59
Condon	Gilliam	2,884	.....	.....	.....	.....	.....	.....	.....	.....	.....	41.10	67.80	47.90	54.11	76.74	54.78	69.55	44.16	55.38	69.97	36.22	71.17	48.51	45.95	55.38	48.45	63.98	49.80	59.62	42.88	40.41	60.39	50.36	.....
Coquille River Light	Coos	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cornucopia	Baker	4,400	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.13	56.21	34.39	45.71	50.23	33.29	50.31	.....	44.16	29.94	48.45	47.02	39.27	.....	44.10	49.67	38.54	43.31	55.93	53.47
Corvallis	Benton	266	34.82	44.99	31.88	43.04	46.44	43.74	57.76	43.61	35.02	49.69	38.49	41.36	54.02	.....	.....	.....	20.20	29.47	12.54	.....	.....	.....	38.46	46.81	35.76	44.13	36.82	46.65	39.13	33.52	50.57	37.12	41.05
Crescent	Klamath	4,452	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.62	14.79	11.49	13.02	12.24	7.83	9.90	.....	15.43	23.79	18.89	18.24	21.31	20.90	16.06	18.42	.....	.....	.....
Dayville	Grant	2,200	.....	.....	.....	.....	.....	8.39	14.88	13.74	9.16	15.45	14.39	10.22	14.01	75.26	105.72	60.87	89.79	.....	.....	105.08	80.23	75.13	100.24	12.67	12.35	13.70	12.58	11.39	7.82	11.05	10.82	11.14
Deadwood	Lane	350	.....	.....	.....	.....	.....	69.07	.....	.....	.....	.....	80.23	91.30	106.49	.....	.....	.....	.....	.....	.....	.....	74.49	62.73	92.95	81.43	102.12	.....	.....	.....	98.79	79.70	111.38	95.64	.....
Detroit	Marion	1,452	.....	.....	.....	.....	.....	9.75	.....	15.41	10.19	16.22	.....	.....	.....	50.12	59.16	38.60	52.58	48.19	48.96	56.45	53.15	6.65	8.55	11.04	6.81	.....	.....	.....	.....	.....	73.62	57.78	73.06
Diamond	Harney	4,300	.....	19.31	11.10	13.07	16.66	.....	.....	.....	.....	.....	.....	.....	67.59	.....	.....	.....	.....	.....	.....	.....	.....	39.36	59.46	44.25	46.53	49.51	52.92	51.06	43.82	47.61	47.25	58.67
Doraville	Columbia	600	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	42.61	31.89	32.51	45.40	57.37	30.93	53.35	39.61	26.28	56.73	39.67	46.17	46.92	52.76	40.36	39.67	57.48	46.80	40.01
Drain	Douglas	300	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.24	11.06	19.22	14.33	13.06	18.30	18.53	12.72	13.37	17.42	11.16	17.48
Dufur	Wasco	2,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.83	6.86	13.09	11.70	7.44	12.47	15.52	9.38	7.83	10.76	12.13	11.36
Echo	Umatilla	625	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.88	9.01	7.58	10.61	10.54	6.23	9.59	6.72	5.54	11.56	12.13	.....	.....	.....	.....	.....	.....	.....	.....
Ella	Morrow	830	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.21	50.71	29.95	37.55	46.27	27.22	8.70	11.66	35.22	31.66	.....	39.83	48.18	41.17	31.40	46.27	36.67	36.60
Eugene	Lane	449	.....	44.76	29.25	42.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	69.80	102.48	62.11	82.50	84.84	.....	39.16	33.20	30.21	43.58	.....	.....	.....	.....	.....	.....	.....	.....	.....
Falls City	Polk	355	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	68.67	49.71	.....	.....	.....	.....	.....	.....	.....	74.05	66.49	71.34
Florence	Lane	75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	65.03	54.06	76.11	66.87	81.68	74.29	71.50	.....	57.61	.....	72.35	71.18	11.04
Fremont	Lake	4,300	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.46	7.71	9.79	9.81	.....	8.22	11.43	4.45	.....	.....	.....	.....	.....
Gardiner	Douglas	39	63.26	87.83	75.64	83.21	79.56	81.86	95.12	78.19	66.60	96.38	71.72	82.40	100.44	72.67	103.56	58.88	79.26	83.86	58.35	89.44	70.23	60.31	77.96	68.68	85.54	.....	.....	.....	.....	.....	.....	.....	.....
Glendale	Douglas	1,441	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	26.66	52.45	49.13	37.66	38.79	27.55	21.89	39.53	29.91	43.45	38.00	46.97	.....	.....	.....	.....	.....	.....
Glenora	Tillamook	575	.....	.....	104.37	151.38	139.98	116.82	167.29	156.53	107.97	162.48	132.49	115.68	147.48	129.15	144.87	97.33	140.01	125.43	115.95	149.26	131.78	98.53	144.58	105.95	127.78	.....	.....	.....	.....	.....	.....	.....	.....
Government Camp	Clackamas	3,890	.....	.....	.....	.....	.....	.....	124.35	103.80	87.93	124.35	80.92	68.58	83.30	73.86	79.50	65.41	72.02	69.32	75.56	93.30	83.98	77.53	98.05	.....	.....	.....	94.72	93.13	.....	91.96	85.95	101.36
Grants Pass	Josephine	956	37.25	33.58	23.95	32.95	36.57	27.58	39.56	29.04	17.77	39.04	29.50	30.22	39.25	36.19	43.76	20.36	35.22	39.20	25.45	43.83	27.89	21.50	33.60	28.73	31.37	25.38	31.44	25.50	23.61	30.83	24.20	22.14
Grass Valley	Sherman	2,381	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.10	.....	8.71	12.00	13.43	6.38	11.77	10.81	.....	16.74	14.64	9.64	.....	.....	.....	.....	.....	.....	.....
Gumboot	Wallowa	4,500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	22.32	22.73	28.83	29.94	30.10	31.00	33.13	26.33	22.10	20.95	27.72	28.50
Headworks	Clackamas	719	.....	.....	.....	.....	.....	.....	.....	.....	11.42	12.98	.....	80.87	75.87	90.04	68.46	75.95	61.10	78.92	81.36	64.03	51.54	74.00	66.07	81.79	72.52	70.30	83.48	89.11	81.71	64.03	90.72	78.95	91.95
Heppner	Morrow	1,950	12.39	16.20	18.20	18.29	15.36	.....	.....	.....	.....	.....	.....	.....	15.17	.....	.....	8.71	15.07	14.29	11.42	11.81	8.74	10.55	18.72	15.30	10.76	15.85	17.40	14.62	15.22	12.94	16.64	12.72
Hermiston	Umatilla	451	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.20	4.79	9.12	6.78	5.00	9.24	8.23	6.22	8.41	13.56	7.89	6.53	9.25	10.51	9.82
Hilgard	Union	2,997	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	17.90	18.36	27.25	23.75	12.48	16.07	24.47	29.99	24.92	22.20	31.64	27.14
Hood River	Hood River	350	50.95	36.61	33.24	54.17	48.29	41.48	51.36	46.87	31.07	44.18	31.08	36.88	42.00	30.22	35.23	25.02	35.71	33.43	25.65	28.41	21.47	18.61	32.18	22.48	24.70	50.21	38.34	32.25	25.44	35.20	32.42	37.94
Howardville	Wallowa	3,600	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.28	20.81	34.68	34.34	26.60	29.15	29.33	33.18	25.92	23.76	34.77	32.49
Ibex Mine	Grant	6,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	26.48	25.51	24.76	35.21	27.27	28.66	33.57	32.24	24.10	32.38	30.99	29.80
Jacksonville	Jackson	1,640	27.72	27.92	16.78	28.40	29.92	20.73	28.78	22.86	17.84	33.63	26.43	30.37	32.64	32.77	41.70	17.06	29.09	35.26	19.05	39.45	23.83	16.58	28.79	25.13	21.76	18.61	22.98	22.68	19.62	21.76	23.60	23.38
Joseph	Wallowa	4,400	18.88	26.68	18.56	20.48	17.40	16.08	17.12	15.21	17.14	17.63	16.42	11.74	15.88	17.08	21.04	16.12	22.98	20.67	16.28	21.73	21.55	19.42	22.46	23.23	24.57	.....	22.90	28.65	.....	.....	20.14	27.18
Kingman	Malheur	2,217	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.04	8.32	14.87	16.67	10.02	17.67	8.19	9.25	13.42	9.41	7.02	6.81	8.53	8.10	8.04	7.26	8.12	8.35
Klamath Falls	Klamath	4,100	.....	.....	.....	.....	.....	.....	.....	.....	16.41	25.16	19.45	18.56	19.99	11.26	17.46	20.29	18.02	22.08	21.31	15.11	17.24	14.70	9.71	19.56	16.11	11.42	11.72	10.98	10.22	9.51	9.40	12.22	11.94
La Grande	Union	2,784	16.54	21.54	.....	.....	.....	.....	.....	.....	8.19	.....	.....	15.10	16.75	15.88	16.11	21.47	9.92	19.71	27.16	.....	.....	21.06	15.52	28.41	25.28	12.76	18.61	15.60	20.70	16.58	19.18	24.06	23.95
Lakeview	Lake	4,950	.....	24.55	19.57	.....	27.04	21.12	12.09	.....	.....	.....	.....	94.52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.33	10.82	12.12	11.60	10.04	7.59	10.27	13.99	9.94
Langlois	Curry	500	.....	.....	84.71	102.05	109.95	101.80	14.62	20.31	16.02	118.01	94.41	81.79	108.17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Lilyglen	Jackson	4,557	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29.47	30.27	37.38	38.39	30.27	30.86	33.18	29.13	28.34	33.48	.....	.....	.....
McKenzie Bridge	Lane	1,400	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	85.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
McKinley	Coos	140	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	69.84	.....	.....	.....	.....	.....	.....	.....	.....
McMinnville	Yamhill	154	42.35	51.46	34.57	49.93	53.40	49.62	64.92	55.07	56.47	82.73	59.35	61.97	87.09	64.53	82.22	53.12	67.33	86.11	58.45	77.02	74.90	57.02	50.94	73.14	69.35	61.17
Marshfield	Coos	40	.....	.....	.....	.....	.....	.....	.....	.....	38.93	56.68	47.40	51.75	61.97	59.67	91.52	49.82	68.03	82.89	48.27	89.46	50.36	42.57	31.48	47.15	40.25	43.23
Maury	Crook	4,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	77.88	40.32	53.35	35.30	41.49	47.60	36.38	47.76	75.82	59.96	51.41	72.36	68.41	67.33
Medford	Jackson	1,425	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	58.21	82.84	49.18	65.60	78.73	47.47	78.95	57.59	56.16	41.43	49.92	37.11	43.15	42.42	16.50	10.64	8.91	7.64	.....	16.21
Merrill	Klamath	4,070	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.59	11.43	.....	70.61	58.98	75.91	68.97	14.52	16.91	14.69	15.14	16.33	9.71
MiramonteFarm	Clackamas	162	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.83	17.03	14.87	17.50	.....	11.79	6.86	.....	13.32	.....
Moro	Sherman	1,836	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	51.17	55.64	44.04	54.19	45.50	36.21	49.09	43.15	42.52	50.07	36.75	43.52	32.83	39.92	43.05	32.14	45.20	10.01	14.86	24.84	19.94	7.65	14.46	11.35	10.63	48.29	48.92	.....
Mount Angel	Marion	485	37.39	53.32	35.20	47.28	47.26	47.45	55.26	49.85	42.23	48.67	46.76	43.14	52.79	35.37	49.56	37.86	50.80	59.39	45.41	54.17	40.89	38.50	14.85	48.57	42.54	41.82	42.69	51.23	43.29	34.81	12.09	.....	12.63
																							10.39	9.20	13.33	12.17	11.32	14.89	14.46	11.33	10.63	57.77	51.52	54.17
																							45.34	41.13	51.16	44.31	47.64	46.95	57.36	50.53	40.53			

Nehalem	Tillamook	10						105.07	132.73	122.81	100.73	134.36	116.48	103.02	125.08	114.38	109.76	82.48	114.37	98.88																	
Newport	Lincoln	128				62.99	71.11	74.59	91.86	69.28	63.73	90.19	75.61	69.99	86.22	60.09	74.53	52.16	70.43	63.82	58.49	74.47	55.73	43.83	73.78	73.31	76.60	69.80	79.60	72.38	60.55	77.67	75.14	85.02
Ochoco	Crook	3,200																					18.65	13.03	21.61	15.27	14.86	17.60	19.55	14.41	15.92	19.89	15.47	
Paisley (near)	Lake	4,400																			15.60	7.98	10.80	6.57	9.88		10.63	12.97	15.24	16.45	13.36	6.70			
Parkdale	Hood River	1,450																					39.58	23.44	35.75	28.67	27.44	31.84	46.86	39.60	31.92	40.57	36.86	
Pendleton	Umatilla	1,070	10.74	14.78	12.43		16.38	10.47	14.99	18.48	11.23	20.08	18.22	14.64	14.90	11.08	14.92	13.71	15.81	13.86	8.07	13.86	14.06	8.20	19.54	17.52	10.77	15.19	16.92	13.65	11.01	13.93	17.26	17.69
Pilot Rock	Umatilla	1,817																				11.12	12.23	10.90	22.81	17.51	10.85	15.08			11.51	14.30	15.48	13.32
Portland	Multnomah	153	40.38	47.41	33.58	39.03	39.32	30.76	44.13	43.01	33.90	42.21	38.22	41.05	50.15	35.62	46.37	34.10	43.29	42.89	34.37	43.75	38.65	33.28	43.47	36.30	36.67	41.30	45.77	40.50	31.50	45.70	41.17	43.21
Port Orford	Curry	100																	85.15	104.71	67.65	118.64		56.41		74.24	86.90	55.30				66.28	69.55	81.44
Prairie City	Grant	3,425																							22.56	16.53	13.78	15.30	16.16	13.95	11.33	14.09	16.13	15.75
Prineville	Crook	2,864								11.64	7.87	8.18	7.74	7.82	8.76		10.64	7.92	9.35	13.31	6.73	10.76		7.10			7.46	8.65	9.28	7.23	7.41	9.08			
Prospect	Jackson	2,800																	38.59		36.24	58.29	42.32	36.47	50.98	37.36	35.99	35.34	40.80	37.01		42.13	42.58	45.13
Ramsey	Wasco	1,350														12.82	19.01	14.55	15.64	22.06	8.98	15.57	14.61	12.67	20.37	13.53	14.29	17.26	16.76	12.58					
Richland	Baker	2,213													19.11	18.70	19.31	10.63	13.21	8.18	7.34	10.29	11.04	7.68	10.42			10.28	9.13	10.71	9.07	9.85	11.17	
Riddle	Douglas	715											25.50	31.06	36.61												28.91	26.53	30.57		23.01	36.92	27.48	25.17
Riverside	Malheur	3,000									4.55	12.34	8.58	7.35	8.54		8.33	8.27	15.46	12.99	6.82	10.76	11.18	8.55	13.63	18.30	8.89	9.45	12.31			9.15	7.77	9.40
Roseburg	Douglas	510	34.65	46.90	28.88	37.86	44.29	29.92	43.69	34.83	25.93	42.97	29.74	34.37	39.58	29.50	43.42	21.14	30.18	42.12	24.18	39.07	28.97	24.58	37.97	26.53	27.07	29.70	33.45	28.02	24.85	38.45	28.65	25.63
Salem	Marion	130				49.08	48.62	47.13	54.93	46.53	34.19	48.12	37.22	37.42	42.55	24.56	42.08	28.49	34.01	37.10	26.76	39.59	31.89	27.55	35.72	31.75	35.87	32.55	44.76	32.82	27.92	41.91	40.78	43.12
Siskiyou	Jackson	4,125													35.55							47.73	29.24	29.07	39.90	36.97	36.40	43.37	43.33	31.52	31.73	42.79	40.71	37.35
Sparta	Baker	4,150			18.06	23.59		20.61	30.49	29.47	23.41	33.77	23.04	20.69	23.57	22.36	23.51	15.36	17.34	15.20	14.13	20.93	23.34	20.89	25.75	21.66	14.80	28.72	17.58	19.06	16.09	17.99	19.92	13.88
Stafford	Clackamas	400								58.78	41.47	58.72	52.12	53.78	58.17	45.91	54.82	38.43	54.31	49.03	42.60	53.81	49.49	44.22	52.77	45.37	45.22			46.04					
Starkey	Union	3,680																					13.45	14.68	24.44	23.19	13.56	16.82	17.69	17.06	13.32	16.08	19.72	21.62
The Dalles	Wasco	96	12.28	12.12	11.97	17.97	18.02	13.88	16.76	16.60	7.58	16.74	13.62	15.83	17.43	12.77	15.94	11.79	14.84	20.06	8.18	16.05	14.56	8.99	16.72	14.16	11.36	15.87	15.54	12.54	11.99	15.19	12.88	21.70
Tillamook	Tillamook	31								130.90	120.90	127.99	111.74	107.42	132.13	111.71	115.96	78.66	108.61	83.11	76.74	84.65	83.93	63.59			95.82		104.10	95.87					
Toledo	Lincoln	75			61.61	87.56		66.55	98.07	89.73	67.84	76.60	59.67	64.23	89.36	65.04	95.59	60.53	83.60	77.22	76.80	81.38	64.70	50.32	74.88	80.74	85.95	79.02			72.25	78.88			
Umatilla	Umatilla	340						6.80	8.49	10.43	4.58	10.36	7.97	7.57	8.70	5.88	7.74	6.67	7.76	10.33	5.92	7.46	8.24	6.98	8.88	9.50	7.29	8.24	11.58	6.68	5.72	7.81	9.59	8.46
Vale	Malheur	2,242			8.31	9.18	9.15	7.48	12.52	12.33	6.79	10.72	9.21	9.22	9.60	9.45	15.19	10.42	10.07	11.09	8.03	9.39	9.09	8.47	12.29	12.31	6.46		5.97					
Valley Falls	Lake	4,250																						12.18	13.86	13.71	10.63	14.68	13.12	10.01	7.49	8.84	13.09	12.03
Wallace Orchard	Polk	170																					37.79	35.65	43.97	36.47	42.30	39.29	51.93	40.52	28.03	48.18	39.26	40.57
Wallowa	Wallowa	2,935															18.33	14.52	19.13	17.62	12.74	18.91	18.75	13.09	20.17	23.88	14.15	17.31		21.23	16.77	12.59	16.99	20.69
Warmspring	Jefferson	1,500														8.63	16.26	9.92	9.39	16.18	7.13	12.76	11.32	6.87		10.00	7.74			8.06	9.35		6.81	11.36
Wasco	Sherman	1,263																			7.02	13.86	11.84	10.13	14.81	12.20	10.43	14.87	14.10	11.84	11.14	13.66	12.77	14.23
Welches	Clackamas	1,435																					80.00	64.32	92.12	80.73	73.48		70.98	91.58	60.27	81.09		92.13
Weston	Umatilla	1,800						15.25	25.76	25.91	19.23	33.75	29.96	22.41	28.52	22.73	28.34	25.83	29.59	26.37	14.45	22.19	18.90	18.05	26.74	23.87	15.43	23.49	27.98	21.01	16.24	19.72	24.13	23.10
Williams	Josephine	1,385						28.69	39.56	29.35	18.00	37.00	30.38	31.42	38.81	38.50	44.45	19.79	35.76	41.90	31.70	57.57	27.93	19.34	33.43	29.10	31.75	27.38						
Yonna	Klamath	4,146																			7.92	19.11	15.47	10.77	18.46	14.59	14.04		11.11	10.05	8.23	8.14	13.51	11.16

THE RAINFALL OF BRAZIL.

ALFRED J. HENRY.

Dr. Sampaio Ferraz, the Director of the new Brazilian Meteorological Service, in his bulletin[1] of normal values presents monthly means of precipitation and other climatic elements for 91 stations throughout Brazil.

We are especially interested in the statistics of precipitation and have therefore summarized them for the benefit of readers of the REVIEW who may not have access to the original publication.

As indicated in the preface of the bulletin, it is concerned mainly with the observations made during the 11 years 1909–1919. It must happen, therefore, that in cases where the station was in operation prior to 1909 the full record of observations has not been included in the published mean values. Caution must therefore be used in regard to the mean values for certain stations. A single example will illustrate the point. Recife, sometimes called Pernambuco, has a rainfall record extending back into the eighties and it has been discussed in several publications; *Meteorologische Zeitschrift* for September, 1886, gives the annual mean as 2,972 millimeters (8 years). In the same publication for July, 1902, the annual mean 21 years' observations is given as 2,147 millimeters. The *Quarterly Journal Royal Met. Soc.* **36**:57 gives the annual mean as 1,934 millimeters, 19 years' observation. The bulletin under discussion gives the mean as 1,193 millimeters, 9 years' observations, 1911–1919. Of course the differences in the annual mean here pointed out are due to the fact that different authorities have used periods of observation that differ from each in the years considered. Doubtless the adjustment of the earlier observation and the combination of the entire record in a homogeneous series is reserved for a future publication.

The geographical coordinates of the rainfall stations are given in the table below. The height above sea level given in the table is that of the barometer cistern at the station. This elevation will not differ materially from that of the rain gage.

TABLE 1.—*Geographical coordinates of meteorological stations in Brazil.*

State and station.	South latitude.	West longitude (Greenwich).	Establishment of station.	Elevation barometer cistern above M.S.L. (meters).	Altitude top of rain gage above ground (meters.)
	° ′ ″	° ′ ″			
Amazonas.					
Manáos	3 08 1	60 01 5	Jan., 1910	44.9	16.0
S. Gabriel	0 06 7	67 02 1	Jan., 1910	.....	2.5
Parintins	2 38 0	56 44 3	Jan., 1910	.....	2.0
Bôa Vista	2 49 0	60 41 3	Jan., 1910	.....	.....
Remate dos Males	4 20 6	70 23 9	Jan., 1910	.....	2.0
Coary	4 21 9	63 03 5	Jan., 1910	.....	2.1
S. Felippe	6 43 0	69 57 0	Jan., 1910	.....	2.0
Para.					
Salinas	0 35 2	47 21 5	Jan., 1910	.....	1.5
Maranhão.					
S. Luiz	2 31 5	44 16 8	Jan., 1909	20.0	1.5
Turyassú	1 42 8	45 26 5	June, 1911	15.0	1.5
Barra do Corda	5 30 5	45 15 9	Jan., 1912	81.0	1.5
S. Bento	2 40 8	44 50 8	Aug., 1912	11.0	1.5
Imperatriz	5 31 6	47 54 6	July, 1913	95.0	1.5
Ceará.					
Porangaba	3 46 7	38 32 6	Mar., 1911	27.0	1.5
Quixeramobim	5 16 0	39 15 1	Jan., 1896	207.0	1.5
Guaramianga	4 15 8	39 01 4	Jan., 1911	825.0	1.5
Quixadá	4 55 4	39 08 3	Mar., 1911	180.0	1.3
Mondubim	3 46 1	38 34 7	Mar., 1911	.....	1.4
Macaty	4 37 0	37 45 3	Jan., 1910	.....	1.5
Rio Grande Do Norte.					
Natal	5 46 7	35 18 4	July, 1904	3.0	1.5
Nova Cruz	6 25 7	35 27 0	Aug., 1911	77.8	1.3
Macáu	5 05 7	36 38 3	Jan., 1910	6.0	1.5

[1] MO. WEATHER REV., June, 1922, **50**: 309.

TABLE 1.—*Geographical coordinates of meteorological stations in Brazil*—Continued.

State and station.	South latitude.	West longitude (Greenwich).	Establishment of station.	Elevation barometer cistern above M.S.L. (meters).	Altitude top of rain gage above ground (meters).
	° ′ ″	° ′ ″			
Parahyba.					
Parahyba	7 6 6	34 56 1	Mar., 1912	30.0	1.5
Pernambuco.					
Recife	8 5 1	34 51 1	Jan., 1900	29.6	26.7
Fernando Noronha	3 50 0	32 55 5	Jan., 1910	95.0	1.5
Nazareth	7 46 7	35 15 2	Sept., 1911	82.0	1.5
Jaboatão	8 6 9	35 5 0	Aug., 1911	50.0	1.5
Goyanna	7 35 0	34 58 4	Aug., 1911	14.0	1.3
Pesqueira	8 45 0	35 15 0	Jan., 1913	.....	1.5
Garanhuns	8 53 4	36 24 1	Feb., 1913	848.0	1.5
Barreiros	8 22 4	37 14 0	Sept., 1911	725.0	1.5
Alagoas.					
Satuba	9 35 4	36 44 6	Jan., 1911	6.0	1.5
Pão d'Assucar	9 43 9	37 27 3	Oct., 1912	49.0	1.5
Maceió	9 40 2	35 44 0	Jan., 1909	.....	1.9
Sergipe.					
Aracajú	10 54 9	37 3 5	Jan., 1909	4.0	7.0
Bahia.					
Ondina	13 0 0	38 30 0	Jan., 1909	47.0	1.5
Caetité	14 2 0	42 38 6	Jan., 1909	900.0	11.5
S. Bento das Lages	12 35 0	38 45 0	Jan., 1912	32.3	1.5
Morro do Chapéo	11 32 9	41 14 4	Mar., 1913	1080.0	1.5
Rio de Janeiro.					
Campos	21 45 4	41 19 9	June, 1911	10.2	1.5
Vassouras	22 24 0	43 49 0	June, 1911	453.9	1.5
Rio de Janiero	24 54 23	43 10 21	Jan., 1882	61.4	2.0
Rezende	22 28 4	44 26 8	May, 1911	399.2	1.5
Petropolis	22 30 9	43 10 0	Sept., 1912	813.0	1.5
Therezopolis	22 26 7	42 55 3	July, 1913	910.0	1.5
Friburgo	22 17 3	42 31 9	Jan., 1901	845.9	1.5
Alto do Itatiaya	22 24 8	44 50 0	Mar., 1914	2280.0	1.5
São Paulo.					
Maristella	22 57 7	45 12 5	July, 1912	600.0	1.5
Bandeirantes	22 36 0	44 28 0	Dec., 1913	533.2	1.5
Parana.					
Paranaguá	25 34 0	48 30 0	Jan., 1910	4.0	1.5
Santa Catharina.					
Florianopolis	27 36 0	48 30 3	Jan., 1909	3.0	4.6
Therezopolis	27 48 0	48 45 6	Mar., 1911	220.0	1.5
Camboriû	27 1 6	48 38 3	Oct., 1911	5.0	1.5
Blumenáu	26 55 3	49 9 2	Jan., 1864	24.0	1.5
Brusque	27 5 3	48 59 2	Jan., 1906	25.0	1.5
Curitybanos	27 17 1	50 41 0	Apr., 1911	900.0	1.5
Ilha da Paz	26 11 5	48 30 7	Jan., 1909	.....	1.7
Itajahy	26 53 11	48 38 7	Mar., 1911	.....	1.4
Cabeçudas	26 57 0	48 30 0	Jan., 1911	.....	1.4
Porto Bello	27 10 2	48 33 7	Apr., 1911	.....	1.6
Campos Novos	27 24 1	51 13 5	Mar., 1911	.....	2.0
Naufragados	27 50 5	48 34 7	Jan., 1911	.....	1.5
Rio Grande do Sul.					
Porto Alegre	30 1 9	51 13 2	Jan., 1910	11.2	1.5
Santa Maria	29 41 4	53 48 7	Jan., 1912	139.0	1.5
Uruguayana	29 45 2	57 4 8	Feb., 1912	374.5	1.5
S. Victorio do Palmar	33 31 2	53 21 8	Oct., 1912	5.0	1.5
S. Anna do Livramento	30 53 3	55 31 9	June, 1912	210.0	1.5
Minas Gacres.					
Bello Horizonte	19 54 9	43 55 7	Jan., 1910	857.0	1.5
Juiz de Fóra	21 45 6	43 10 7	Jan., 1910	680.0	1.5
Cocambú	21 58 7	44 56 2	Aug., 1911	890.5	1.5
Mar de Hespanha	21 56 0	42 47 0	Aug., 1913	450.0	1.5
Uberaba	19 44 6	47 56 2	Jan., 1897	760.0	1.5
Montes Claros	16 43 0	43 50 0	July, 1905	615.2	1.7
Pirapora	17 21 1	41 56 9	Jan., 1912	471.8	1.5
Theophilo Ottoni	17 45 0	41 26 3	Feb., 1911	305.0	1.5
Cachoeira do Campo	20 21 0	43 40 0	July, 1914	1104.0	1.7
S. João Evangelista	18 25 0	42 47 0	Jan., 1914	680.0	1.5
Oliveira	20 38 0	44 42 0	July, 1913	962.0	1.5
Araguary	18 38 5	48 11 3	Oct., 1913	920.0	1.5
Monte Alegre	18 6 0	49 6 0	Nov., 1913	696.4	1.5
S. Francisco	15 56 9	44 52 2	June, 1912	449.8	1.5
Curvello	18 45 7	44 25 8	Sept., 1912	615.0	1.5
Januaria	15 29 4	44 21 6	June, 1912	438.9	1.5
Goyaz.					
Goyaz	15 55 4	50 7 9	May, 1911	520.0	1.5
Catalão	18 10 4	47 58 3	Oct., 1912	830.0	1.5
Pyrenopolis	15 51 7	48 57 3	Apr., 1913	750.0	1.5
Formoza	15 32 1	47 18 3	Jan., 1913	912.0	1.5
Matto Grosso.					
Cuyabá	15 35 9	56 6 0	Dec., 1900	165.0	1.5
Corumbá	20 28 1	57 39 2	May, 1912	116.0	1.5
S. Luiz de Caceres	19 00 0	57 41 7	May, 1912	118.0	1.5

TABLE 2.—*Monthly and annual means of precipitation at 94 stations in Brazil (in millimeters).*

States and stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Amazonas.													
Manáos	210.9	203 3	204.6	214.3	167.7	99.5	46.2	33.0	35.3	116.7	114.6	208.0	1,654.1
S. Gabriel	174.4	222.5	188.3	127.2	321.7	172.9	189.9	137.9	135.8	154.7	192.1	198.7	2,216.1
Parintins	175.5	215.5	348.8	257.7	222.1	140.1	105.8	83.6	45.2	68.1	90.0	112.3	1,864.7
Bôa Vista	15.2	60.6	95.0	129.9	210.2	329.8	240.6	181.1	43.2	43.6	16.9	29.9	1,396.0
Remate dos Males	374.3	285.6	385.6	293.3	268.5	151.6	143.5	164.0	165.8	273.6	269.2	361.6	3,137.5
Coary	240.8	260.9	271.9	251.2	217.7	131.2	80.8	74.1	94.7	147.1	133.5	211.6	2,115.5
S. Felippe	295.7	345.2	339.5	263.7	176.6	59.0	65.6	107.0	192.6	257.8	308.6	280.0	2,691.3
Para.													
Salinas	121.9	306.8	450.0	384.4	236.3	133.1	80.9	20.3	0.0	1.8	1.4	50.5	1,787.4
Maranhão.													
S. Luiz	190.5	243.9	477.7	416.4	320.7	144.9	114.9	29.8	12.4	10.6	18.1	68.9	2,048.8
Turyassú	228.2	309.2	425.0	417.6	237.8	210.8	132.4	69.1	11.0	11.5	11.4	57.4	2,157.6
Barra do Cordo	192.1	178.8	161.6	98.5	61.4	19.5	8.1	12.1	26.9	42.8	84.3	121.1	1,007.2
S. Bento	215.8	240.3	346.2	337.1	265.1	195.6	68.3	44.4	8.6	15.9	28.4	111.3	1,877.0
Imperatriz	262.1	245.5	249.8	153.7	112.2	11.5	10.7	20.5	20.1	74.8	80.1	169.1	1,410.1
Ceará.													
Porangaba	124.6	281 8	282 7	276 8	228 6	138.6	25.5	39.9	21.6	3.4	14.4	33.4	1,471.3
Quixeramobima	76.0	100.6	150.6	129.2	93.2	40.8	19.7	12.3	1.1	0.7	3.2	30.0	657.4
Gauaramiang	181.4	239.6	280.9	248.9	206.2	170.8	72.3	101.6	52.4	41.5	50.2	74.3	1,720.1
Quixada	125.6	139.2	194.0	123.0	116.2	76.2	15.4	25.9	3.4	5.9	7.3	41.3	873.4
Mondubim	139.6	269.3	294.0	262.1	216.8	121.7	40.9	50.1	28.0	8.4	22.8	36.6	1,490.3
Macaty	79.5	186.7	370.9	247.0	105.4	53.1	17.8	20.5	7.6	10.1	8.4	39.0	1,146.0
Rio Grande do Norte.													
Natal	59.6	123.0	143.9	219.7	144.4	315.6	199.8	123.7	35.7	11.6	13.9	26.1	1,417.0
Nova Cruz	73.7	77.6	142.9	127.1	100.7	158.8	91.9	78.4	13.3	6.5	3.0	8.1	882.0
Macáu	66.8	164.8	164.7	97.0	87.7	27.7	30.3	21.7	10.8	4.3	5.9	17.6	699.3
Parahyba.													
Parahyba	91.8	149.0	161.4	165.4	290.4	355.0	224.5	161.9	62.6	21.2	32.0	48.3	1,763.5
Pernambuco.													
Recife	46.6	106.7	115.2	95.1	235.8	205.3	155.6	130.0	42.2	15.3	20.0	25.0	1,192.8
Fernando Noronha	63.6	110.7	192.9	247.9	221.3	113.4	63.8	33.9	7.4	6.4	6.6	15.2	1,083.1
Nazareth	105.8	137.9	149.9	116.6	223.4	266.8	183.3	133.5	44.9	19.4	18.6	36.3	1,376.4
Jaboatão	123.6	188.9	186.6	178.7	329.0	375.7	298.1	224.5	88.2	32.6	36.2	47.3	2.109.4
Goyanna	106.0	166.1	158.5	164.8	263.1	266.8	191.0	152.8	58.7	19.0	29.6	31.8	1,608.2
Pesqueira	76.0	80.2	66.8	66.7	67.8	74.9	96.3	41.2	30.5	21.1	4.1	26.1	651.7
Garanhuns	75.3	63.0	42.3	84.3	132.5	160.4	150.6	124.9	53.6	14.9	16.7	49.8	968.3
Barreiros	130.1	160.4	162.3	159.9	416.9	457.2	403.6	333.6	170.1	55.5	45.2	65.2	2,560.0
Alagoas.													
Satuba	44.6	100.1	111.9	108.2	211.3	297.6	234.6	183.4	116.7	34.0	25.9	51.4	1,519.7
Pão d'Assucar	45.4	19.2	36.6	48.7	54.7	85.7	101.4	61.3	21.8	22.5	33.7	73.1	604.1
Maceió	75.3	87.6	191.5	146.2	346.1	284.8	236.5	170.6	108.7	44.2	27.5	58.1	1,777.1
Sergipe.													
Aracajú	38.9	45.6	105.9	86.6	171.1	128.3	119.2	69.2	39.7	63.1	22.5	57.2	947.3
Bahia.													
Ondina	82.2	122.8	138.8	245.4	259.0	242.6	187.4	123.3	83.7	118.9	119.7	152.4	1,876.2
Caetité	139.1	84.9	80.0	66.7	14.2	10.9	9.4	6.2	23.8	71.4	130.0	150.3	786.9
S. Bento das Lages	109.8	146.9	129.8	209.7	195.3	216.6	264.4	155.8	85.8	128.2	115.7	151.9	1,909.9
Morro do Chapéo	163.1	99.1	93.0	93.8	35.4	34.9	42.2	29.5	19.8	48.9	87.0	168.0	914.7
Rio de Janeiro.													
Campos	155.7	89.0	199.4	97.9	36.8	30.4	22.5	41.9	49.1	129.1	119.6	182.5	1,153.9
Vassouras	200.2	152.8	122.9	58.9	23.9	26.6	15.4	19.3	34.5	122.7	135.9	157.2	1,070.3
Rio de Janeiro	127.7	113.4	139.0	88.1	69.1	72.7	47.6	45.6	75.6	94.1	101.4	130.1	1,105.7
Rezende	296.8	246.8	150.7	110.0	33.5	35.6	31.1	28.5	52.1	130.9	177.4	241.9	1,535.3
Petropolis	292.6	227.1	308.2	157.5	84.7	67.4	60.8	66.9	72.1	188.1	323.3	273.5	2,122.2
Therezopolis	322.5	263.1	336.9	163.3	96.6	68.5	55.8	104.3	136.5	271.0	342.9	372.5	2,533.9
Friburgo	252.2	183.4	194.0	95.5	29.0	19.3	20.2	45.0	23.4	160.9	144.2	252.8	1,420.9
Alto do Itatiaya	387.8	383.9	273.6	192.1	54.1	50.6	57.9	51.0	69.7	204.5	254.2	343.0	2,322.4
São Paulo.													
Maristella	271.7	184.0	132.7	70.6	50.9	34.6	24.6	37.6	54.6	123.0	153.1	217.7	1,355.1
Bandeirantes	291.5	211.9	149.3	156.2	36.9	35.2	26.4	37.4	53.9	119.6	154.9	247.1	1,520.3
Paraná.													
Paranaguá	269.8	255.4	125.8	125.8	89.9	98.7	57.7	77.3	139.3	157.3	143.2	197.8	1,738.0
St. Catharina.													
Florianopolis	142.0	108.2	144.2	71.8	43.1	66.1	39.7	79.8	92.4	87.4	68.2	82.5	1,025.4
Therezopolis	225.4	248.4	190.7	92.1	49.8	119.8	70.9	109.9	235.7	119.5	120.5	128.7	1,711.4
Camboriú	187.1	205.4	148.1	93.7	72.0	89.8	49.6	92.6	115.5	104.7	97.1	127.5	1,383.1
Blumenáu	203.7	263.2	168.1	96.9	61.1	103.5	51.6	100.4	117.5	101.1	74.7	124.2	1,466.0
Brusque	202.2	239.7	191.6	108.0	77.4	103.9	62.0	103.9	153.4	130.6	147.2	162.8	1,682.7
Curitybanos	172.9	144.4	152.6	104.2	85.2	180.9	112.3	117.2	199.4	141.2	112.0	135.8	1,658.1
Ilhá da Paz	178.3	280.2	146.6	114.2	63.7	90.5	59.2	64.1	121.9	130.5	92.9	114.3	1,456.4
Itajahy	183.0	196.3	154.4	83.8	70.3	82.9	55.0	71.8	106.4	105.2	85.6	117.1	1,311.8
Cabeçudas	124.1	179.5	157.5	86.9	72.6	79.7	62.3	76.9	108.4	76.6	89.6	91.2	1,205.3
Porto Bello	179.6	217.7	160.9	97.1	83.0	92.6	52.6	90.0	126.7	117.5	115.7	143.9	1,477.3
Campos Novos	129.5	143.6	143.5	117.1	111.1	180.9	120.7	120.8	192.3	142.9	126.4	116.4	1,645.2
Nau Fragados	99.2	88.2	69.4	41.5	21.1	38.1	45.6	61.6	87.8	87.4	55.9	59.7	755.5
Rio Grande do Sul													
Porto Alegre	121.1	85.5	89.1	124.9	118.9	125.1	99.8	144.9	128.9	68.9	90.1	102.5	1,299.7
Santa Maria	138.2	155.4	169.9	158.0	197.5	160.9	153.7	132.7	165.0	108.1	136.1	119.1	1,794.6
Uruguayana	95.6	100.5	169.1	174.7	153.4	98.1	79.6	74.4	102.4	104.4	111.0	87.9	1,351.1
S. Victorio do Palmar	95.8	115.2	133.6	91.5	148.4	62.0	115.2	105.4	139.1	89.2	83.7	87.0	1,266.1
S. Anna do Livramento	114.9	104.1	157.9	108.0	142.6	84.1	117.4	96.3	126.6	97.3	94.7	99.6	1,343.5

TABLE No. 2.—*Monthly and annual means of precipitation at 94 stations in Brazil (in millimeters)*—Continued.

States and stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Minas Geraes.													
Pello Horizonte	329.9	224.2	163.6	71.8	15.9	12.1	10.3	23.3	37.2	126.3	208.1	277.8	1,433.1
Juiz de Fóra	301.6	161.0	164.2	83.4	21.6	24.0	12.2	23.9	51.7	149.2	186.0	254.2	1,500.5
Caxambú	338.3	177.5	113.8	95.2	29.7	20.6	15.9	23.7	69.2	150.9	187.6	245.4	1,467.8
Mar de Hespanha	267.7	120.4	139.3	81.3	43.1	25.9	12.1	31.5	33.5	137.1	152.4	235.7	1,280.0
Uberaba	256.8	220.0	232.8	148.1	42.9	29.0	12.6	23.2	37.2	104.8	218.9	264.7	1,591.0
Montes Claros	307.5	154.1	133.4	78.2	31.6	1.3	3.0	12.5	14.3	127.6	139.5	233.0	1,236.0
Pirapóra	330.8	166.9	172.1	98.2	8.5	25.0	4.0	16.5	30.6	101.3	151.6	241.2	1,346.7
Theophlo Ottoni	216.5	129.4	177.2	129.0	100.3	35.9	22.1	24.7	28.7	119.3	223.2	243.8	1,450.1
Cachoeira do Campo	274.5	175.1	118.2	124.3	52.3	29.5	11.8	32.1	35.3	130.2	232.0	309.6	1,525.9
S. João Evangelista	254.6	147.5	175.6	116.8	40.9	22.0	9.9	33.8	38.9	131.8	244.0	318.9	1,534.7
Oliveiro	308.7	179.4	215.1	93.9	29.0	26.5	14.4	26.5	35.0	134.0	196.8	248.0	1,507.3
Araguary	324.9	302.2	248.8	167.7	14.4	16.0	20.7	12.1	44.3	197.4	256.6	419.5	2,024.6
Monte Alegre	191.3	148.3	78.1	35.4	18.1	14.4	9.8	30.2	136.2	261.8	330.6	280.1	1,534.3
S. Francisco	300.4	141.3	142.8	88.9	26.9	0.6	5.3	9.6	25.2	104.7	224.8	269.4	1,339.9
Curvello	242.3	107.3	174.0	109.4	15.1	11.1	11.7	13.9	38.9	87.5	207.6	271.9	1,290.7
Januaria	207.6	97.3	118.2	94.4	12.0	1.2	8.6	5.6	36.0	85.9	170.2	228.8	1,065.8
Goyaz.													
Goyaz	307.7	276.0	294.9	124.5	10.6	12.7	0.2	11.2	43.6	123.4	219.2	264.3	1,688.3
Catalão	334.6	247.7	254.6	115.2	33.0	8.9	14.0	8.8	67.4	190.1	223.6	362.8	1,860.7
Pyrenopolis	286.6	229.4	304.3	119.1	35.6	5.7	6.1	11.5	32.8	142.2	210.4	266.5	1,650.2
Formosa	360.3	221.5	166.3	135.1	19.1	3.0	4.5	28.7	48.5	135.0	201.0	376.2	1,699.2
Matto Grosso.													
Cuabá	240.7	214.9	232.9	119.6	48.8	3.9	6.2	51.1	50.1	104.5	165.6	221.9	1,460.2
Corumbá	166.1	158.4	122.9	123.8	84.7	47.7	7.1	34.1	57.9	101.6	151.1	189.7	1,245.1
S Luiz de Caceres	200.7	208.4	145.1	96.2	50.8	18.0	5.6	20.4	48.6	109.6	182.5	190.3	1,276.2
ADDITIONAL STATIONS.													
Ceará.													
Fortaleza[1]	80.0	179.0	297.0	341.0	237.0	120.0	55.0	29.0	16.0	13.0	13.0	38.0	1,418.0
São Paulo.													
Alto da Serra	414.0	396.0	382.0	304.0	214.0	192.0	170.0	204.0	272.0	318.0	348.0	400.0	3,614.0
Santos[2]	302.0	235.0	345.0	212.0	164.0	178.0	114.0	122.0	143.0	182.0	201.0	249.0	2,447.0
São Paulo[2]	231.0	217.0	157.0	75.0	74.0	57.0	34.0	52.0	86.0	114.0	133.0	193.0	1,423.0

[1] Quart. Jour. Roy. Met. Soc. XLV; 69. For the years 1849–1915.

[2] Idem, p. 61.

The rainfall statistics of Table 2 have been grouped by States beginning with the most northerly Amazonas. A cursory examination emphasizes what is already well known, viz, that vast areas in Brazil are not adequately represented by existing meteorological stations. The great interior States of Amazonas, Para, and Matto Grosso having a combined area of four and a quarter million square kilometers are represented by 11 rainfall stations all of which have sufficient length of record to be incorporated into the bulletin of normals. This would give a single station to each 402,190 square kilometers (155,291 square miles).

Various writers have distinguished at least five distinct types of rainfall in South America according to whether there is a single or double maximum and minimum and the season of the year in which the maximum occurs. A simpler classification might be based on the monthly distribution in which we should have a type of single maximum and minimum, respectively, regardless of the time of year they occur. The second type would logically be those distributions which have a double maximum and a double minimum in the course of 12 months, and finally there would be the type in which the monthly distribution is more or less uniform.

The five types now commonly recognized are as follows: (1) A double maximum in the equatorial regions separated by intervals of relatively less rain; (2) a season of well-marked maximum in the rains which may occur in any of the four seasons. There will be, therefore, four subtypes under (2), viz, Winter, Spring, Summer, and Autumn, each of which will obtain in different parts of the continent. Finally, a sixth type, the type of uniform rains is recognized.

In the Tropics the altitude of the sun seems to be the most important control of rainfall; other causes are operative but it is not easy to segregate them. The rainfall of Brazil is best understood by a consideration of the characteristics of the coast as compared with the interior. The coast of Brazil stretches from about 4° north latitude to 33° south latitude. In that distance both the amount and the monthly distribution vary considerably.

I have prepared a series of 24 graphs which illustrate the monthly distribution at a number of points on the coast and in the interior. It is helpful to begin the series with what may be called the oceanic type for the South Atlantic northeast of Cape St. Roque. The meteorological station on the island of Fernando Noronha, established in 1910, furnishes the data for the graph No. 1 of Figure 1. That island is 125 miles offshore and in the region of the southeast trades. The maximum precipitation of the year is reached in April and there is then a rather rapid diminution in the amount until November. Zenith sun is reached on the island on the 1st of April and during that month pressure falls to the lowest point of the year. The wind circulation of the South Atlantic is largely dominated by the strength and position of the semipermanent South Atlantic anticyclone whose normal winter position is within the triangle formed by the islands of Helena, Tristan da Cunha, and Trinidad. The barometer level in this anticyclone sinks to 30.10 inches in April; it is then least effective as a wind control on the Brazilian coast. The prevailing winds at Fernando Noronha during summer (Southern Hemisphere) December–February are southeasterly becoming more southerly in February and backing to between southeast and east in March, April, and May. The force of the winds in January is on the average 6.8 meters per second falling to 5.7 in March and rising to 6.4 in April and 6.8 in May. The greatest force of the wind, 8 meters per second, is reached in July (winter of Southern Hemisphere.) The direction, however, is practically the same throughout the year, viz, southeast to east.

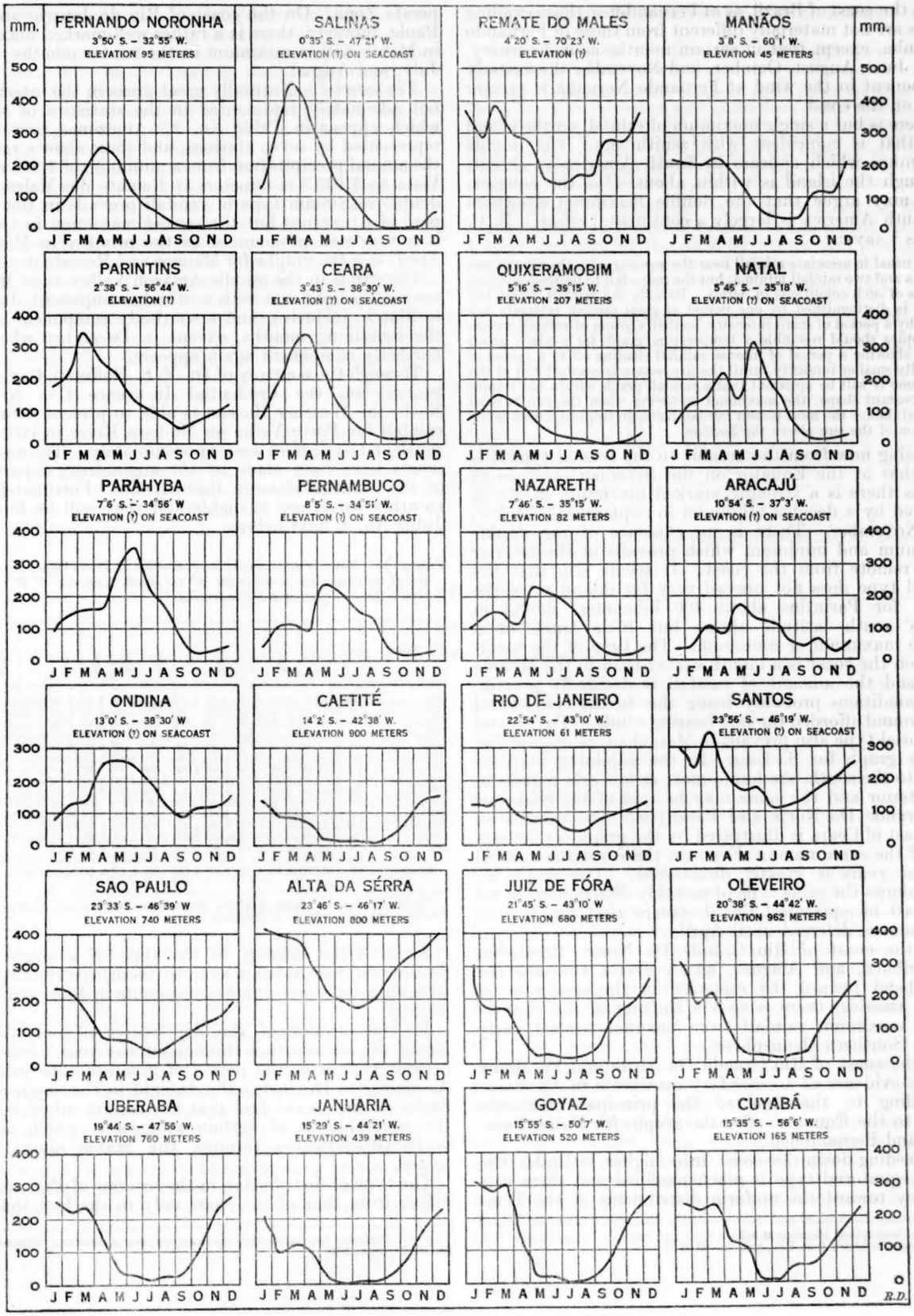


FIG. 1.—Graphs of mean monthly precipitation at various South American stations.

On the coast of Brazil, as at Pernambuco, the prevailing winds are not materially different from those of Fernando Noronha, except that in certain months as in February, May, June, August, October, and November the easterly component in the wind at Fernando Noronha is greater than on the coast.

There is but a single maximum of rainfall on the island and that is coincident with zenith sun. The double maximum which appears in South America is absent, although the island is within about 4° of the equator. This may argue that the double maximum elsewhere in South America is largely a continental effect. B. C. Wallis [2] says:

> It is usual to associate rainfall near the equator with the idea of two maxima and two rainfall minima, but the maps fail to indicate the prevalence of such conditions in Africa. Broadly the rainfall within the tropics is distinguished by one period of great rainfall intensity followed by a period of small intensity, so that a graph of rainfall within the tropics should resemble a temperature graph for a place about 50° N, showing a period of intense rainfall shading off to a period of gradually smaller intensity, until the dry season is reached and at the same time it will be apparent that a rainfall graph within the tropics is of constant shape, the maximum occurring when the sun is most powerful; hence the most potent rainfall factor in tropical Africa is the elevation of the sun above the horizon.

Passing now from the oceanic to the coastal type it is seen that at the Equator on the Brazilian coast as at Salinas there is a strongly marked maximum in March followed by a decided minimum in September, October, and November. There is no evidence of the double maximum and minimum which prevails in the interior quite remote from the coast. It seems also that the coastal type does not prevail very far inland since the graph for Parintins about 400 kilometers inland in 2° 38′ south latitude shows but little trace of a double maximum or minimum. The time of the maximum on the coast is a month earlier than in the oceanic type and the amount of rainfall is decidedly greater, both conditions probably being due to the continental background afforded the rain bearing winds. The coastal equatorial type also prevails in Maranhao, as exemplified by the graph for S. Luiz. In the adjoining State of Ceara to the south, are found more or less arid regions in the interior and the same may be said of the States of Rio Grande Do Norte and Parahyba. The rainfall on the Coast of Ceara is illustrated by the graph for the station of the same name. Even on the coast the rainfall of some years is greatly diminished.[3] The graph for Ceara shows the same type of monthly distribution as for the coast of equatorial Brazil, except that the time of maximum is deferred until April.

On the coast of Rio Grande Do Norte, Parahyba, Pernambuco, and Alagoas, which States embrace the great bend toward the eastward in the continent of South America, there is seen a shifting of the time of yearly maximum rainfall from autumn toward early winter (Southern Hemisphere).

On the coast of Rio Grande Do Norte and Parahyba there is evidence of a secondary maximum in April corresponding to the time of the principal maximum nearer to the Equator. See the graphs for Natal, Parahyba, and Pernambuco.

Proceeding down the coast into higher latitudes the simple equatorial type is much modified and there is a tendency toward the uniform distribution of the Temperate Zone. On the coast of Rio de Janerio and Sao Paulo, however, there is a rather well-marked maximum in March with a minimum in the winter months—June, July, and August.

The interior.—Naturally great areas in the interior are not adequately represented in the statistics of rainfall which appear in Table No. 2. Amazonas, however, is represented by seven stations, and these show a range in the annual precipitation from a minimum of 1,396 at Boa Vista to 3,137.5 millimeters at Remate dos Males. The double maximum type of rainfall prevails in the larger part of Amazonas but the second maximum in October is not so well pronounced as the primary in March or April—see the graphs for Manaos and Remate dos Males.

The winds in the middle Amazon Valley as at Manaos are mostly light east with northerly component, January to March, inclusive, and a southerly component during the remaining months, except in December when the northerly component again appears.

Through the courtesy of Dr. F. L. Hoffman, Consulting Statistician, the Prudential Insurance Co., Newark, N. J., the Weather Bureau is able to present a table of rainfall for Porto Velho on Madeira River in latitude 9 south and 64 degrees west, approximately. The measurements have been made by the engineering department of the Madeira-Mamore Railway Co. Fortunately the monthly totals are available and they will be found in Table No. 3, next below.

TABLE 3.—*Monthly and annual precipitation at Porto Velho, Amazonas, Brazil, approximate position lat. 8° 44′ south, long. 64° 0′ W. Elevation unknown (inches and hundredths).*[1]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1908	14.93	10.66	19.65	4.59	4.79	1.63	0.37	2.36	1.35	9.28	13.74	18.85	102.21
1909	11.23	13.91	13.42	8.19	6.33	.10	.02	.00	2.72	7.62	6.59	19.71	89.84
1910	9.78	10.42	9.81	10.83	1.87	.09	.50	1.69	5.42	9.28	8.31	9.12	77.12
1911	13.62	15.96	9.56	10.54	1.97	1.09	.17	6.77	1.86	6.07	16.21	10.93	88.75
1912	14.43	7.92	8.57	7.37	5.06	1.08	.07	.72	4.26	10.61	10.42	9.52	80.03
1913	11.25	10.48	13.08	10.12	1.12	.00	.13	1.87	3.73	6.26	4.40	6.57	69.01
1914	7.99	11.00	8.90	5.04	2.63	1.43	.09	.34	.86	3.18	2.03	5.06	48.55
1915	5.66	5.60	6.03	3.07	2.92	.00	2.62	4.91	6.29	5.64	11.21	9.87	63.82
1916	20.30	13.66	9.28	11.69	4.25	1.13	.00	1.56	2.72	3.64	11.58	12.27	92.08
1917	17.53	8.78	16.53	10.65	3.84	.30	.29	.00	.00	3.69	9.15	9.00	79.76
1918	5.04	17.13	17.41	7.56	7.81	.79	.31	3.73	5.52	9.64	13.95	24.46	113.35
1919	8.62	21.05	25.11	12.02	6.89	1.41	.14	2.24	8.25	22.78	19.59	17.17	143.27
1920	24.82	20.31	15.91	10.64	10.24	2.72	2.21	4.80	7.41	18.33	14.83	20.77	152.99
1921	24.48	11.27	18.78	12.13	7.60	2.63	.51	4.37	2.52	8.67	.....	.....	.....
Means	13.55	12.72	13.72	8.89	4.81	1.03	.53	2.10	3.64	8.91	10.92	13.34	94.16

[1] Observations made under direction Engineering Department, Madeira-Mamore Railway. Furnished by F. L. Hoffman.

Porto Velho belongs to the type of a single well-pronounced maximum in summer (Southern Hemisphere) with an equally well-marked minimum in June, July, and August.

In the interior of the dry States of northeastern Brazil the distribution throughout the year follows the oceanic type with the period of greatest rains in April. According to Draenert [4] the drought in the northeastern States is due to the fact that the regions affected lie in the rain shadow of certain mountains which stretch northeast-southwest through the States above mentioned.

The type of distribution in the interior of Pernambuco differs from that of the coast only in the fact that the

[2] Scottish Geographical Magazine 30:365.
[3] cf. Mossman in Quart. Jour. Roy. Met. Soc. 45:69-79.
[4] F. M. Draenert, Die Vertheilung der Regenmengen in Brasilien, Meteorologische Zeitschrift, Sept., 1886.

season of greatest rain is slightly later and the amount is greater at points favorably situated with respect to the sea winds. On the other hand, places in the rain shadow of the mountains receive less rain than on the coast.

In Bahia the inland type as represented by the station Caetité is nearly opposite to the coastal type in that the greatest rains occur in the months November–April and the least in winter June–August.

With increasing distance from the Equator the monthly distribution tends toward the equality of the Temperate Zone, although distance from the sea and topographic factors are still controlling influences. The three stations in São Paulo whose graphs are given in Figure 1—Santos on the coast, Alta da Serra, a seaward-facing slope station about 15 kilometers inland, and São Paulo on the interior highlands about 50 kilometers inland—show a considerable difference in the monthly distribution. Santos on the coast has a chief maximum in March, while the slope station, Alta da Serra, has a decided maximum in the summer months, December to February. The total annual amount of rain at that station is, moreover, the greatest reported for any station in Brazil, doubtless due to the topographic factor. The concluding group of interior stations beginning with Juiz de Fora and concluding with Cuyaba illustrate the characteristics of monthly distribution in the interior of the States of southern Brazil. A feature common to all of them is a rainy season in summer and a dry season in winter.

MAXIMUM PRECIPITATION IN 24 HOURS.

Voss, speaking of the maximum precipitation in Brazil for 24, hours, says:[5]

> By far the greatest rainfall within 24 hours fell in the State of São Paulo, Brazil, on the eastern slope of the Serro do Mar at an elevation of 230 meters at kilometer No. 22, on the wire-cable railroad Santos to São Paulo. Here on March 29, 1898, a rainfall of 417 millimeters (16.42 inches) occurred. At just double the elevation at kilometer 25.2, 313 millimeters fell on the same day and at the end of the line, elevation 800 meters, the fall was only 61 millimeters (2.40 inches).

The record of maximum rains in 24 hours in Doctor Ferraz's bulletin refers, of course, to the period 1909–10. I have summarized the data by States and present the results in the table below. The arrangement of States is in the order of magnitude of the 24-hour rains.

TABLE 4.—*Maximum precipitation in 24 hours (by States).*

States.	Amount.		States.	Amount.	
	Millimeters.	Inches.		Millimeters.	Inches.
S. Catharina	289.3	11.39	Alagoas	162.7	6.40
Maranhão	222.7	8.76	Goyaz	160.0	6.30
Minas Geraes	202.7	7.98	Parana	153.0	6.02
Ceara	201.9	7.95	Pernambuco	146.1	5.78
Amazonas	201.0	7.91	Matto Grosso	133.6	5.25
Bahia	193.0	7.60	Rio Grande do S	133.4	5.25
Para	177.6	6.99	Sergipe	122.1	4.81
Rio Grande do N	174.0	6.85	Parahyba	119.0	4.68
Rio de Janeiro	173.0	6.81	São Paulo	98.4	3.87

[5] Voss, Ernst Ludwig, Die Niederschlagsverhältnisse Südamerika, Erganzungsheft No. 157 Petermanns Mitteilungen. S. 30.

THE ETESIENS.

By J. S. PARASKÉVOPOULOS.

[National Observatory, Athens, Greece, May 25, 1922.]

Introduction.—The characteristic north winds which blow during the summer in the region of the eastern Mediterranean, are known as the etesiens. The periodic nature of these winds has been observed since the time of the ancient Greeks, their marked regularity being noted by Hesiodus. In fact, it is because of this characteristic regularity that they are called etesiens.[1] The name itself means "winds blowing periodically every year." Aratus has written on this subject in his *Phenomena*, from which we quote the following:

> When the corn has been harvested and the sun is approaching the constellation of Lion, then the etesiens blow with their full strength in the open sea; navigation with oars is not possible and I want then a large boat.

Theon, the commentator of Aratus, explained the name in a double way:

> The etesiens blow from the time of the morning rising of the constellation of Canis Major, during, at the most, 60 days. They are called etesiens either because they blow each year during certain days, or, more truly, because they are sure to blow when their season comes. At that time, large boats are necessary, because the waves are high and the wind stormy.

Characteristic features of the etesiens.—The method of determining the period during which etesiens blow in Greece has been as follows: I have divided the month into *10-day* periods and noted the number of days during which etesiens have blown in each period rather than counting the number of days in each month. This method has been applied to observations extending over 15 years (1900–1914) and is based on the observations made at the Greek meteorological stations. At these stations observations are made three times daily; at 8 a. m., 2 p. m., and 9 p. m. (Athens mean time). I have selected four stations in the Aegean Sea (Andros, Syra, Naxos, Santorin) and three in the Ionian Sea (Corfu, Zante, Cephallonia). For the station at Athens I have used observations from self-recording apparatus.

Table 1 gives the average number of days having north winds. I have considered as north winds all winds between the directions ENE., N., WNW.

In examining the tabulated results, especially those from the stations of the Aegean Sea and Athens, I found that these summer north winds fall into two definite periods. The maximum of the first period, which is also the shorter, occurs during the last 10 days of May while the maximum of the second period takes place during July and August. The etesiens are thus divided into two classes known as *prodroms* and *etesiens*. Generally speaking etesiens blow from the second 10-day period of May until the middle of October, with two periods of maximum, as just mentioned.

During the first period the etesiens are less strong and more intermittant than during the second. During June these winds are interrupted, and not very frequent. In July and especially in August they are, on the contrary, much more steady and frequent but their occurrence diminishes continually throughout September and October. This distinction was observed as early

[1] The etesiens are known in the Orient under the Turkish name *meltem*.

as the time of Aristotle who writes as follows regarding the etesiens:[2]

TABLE 1.—*Average number of days with north winds,*[1] *1900–1914.*

Month.	Athens.	Aegan Sea.				Ionian Sea.		
		Andros.	Syra.	Naxos.	Santorini.	Corfu.	Argostoli.	Zante.
	d.	d.	d.	d.	d.	d.	d.	d.
May 1–10	5.1	5.3	6.3	6.7	5.8	4.0	6.1	6.4
11–20	4.7	5.1	6.0	7.5	5.5	4.7	7.5	7.6
21–31	7.2	7.3	8.2	8.6	7.1	6.1	8.3	7.7
June 1–10	4.7	5.6	6.7	7.0	5.7	4.5	7.5	7.9
11–20	5.1	6.5	6.1	8.5	5.4	5.7	8.4	8.1
21–30	5.9	8.1	8.4	8.9	7.4	6.3	8.9	8.9
July 1–10	5.3	7.8	8.5	8.5	7.5	5.7	9.1	8.7
11–20	6.4	8.8	8.4	9.3	8.4	6.5	9.0	9.6
21–31	8.4	10.3	10.3	10.7	9.6	6.4	9.8	9.9
Aug. 1–10	7.3	9.3	9.3	9.7	9.1	6.4	9.3	8.8
11–20	7.3	9.0	9.2	9.2	8.5	5.5	9.1	8.7
21–31	8.7	10.3	10.1	10.8	10.1	6.0	9.5	9.9
Sept. 1–10	7.0	8.7	8.9	9.3	8.9	4.6	8.4	8.7
11–20	6.4	8.3	7.7	9.0	7.7	4.3	7.1	7.9
21–30	7.0	8.0	7.9	8.7	8.3	4.6	7.9	7.6
Oct. 1–10	6.1	6.2	6.7	7.9	7.1	4.1	7.8	6.8
11–20	6.7	7.1	7.7	8.1	7.7	4.1	6.2	6.3
21–31	7.4	7.1	8.1	8.7	8.3	3.5	6.2	6.9

[1] In this table, winds of directions between ENE.–WNW. have been considered as north winds.

That is why during the time of the morning rising of Orion there is calm until the time of the etesiens and the prodroms.

The etesiens blow after the solstice and the morning rising of Sirius, they do not blow when the sun is nearest or when it is farthest away; they blow during the day and cease at night.

According to the ancients, therefore, the principal etesiens begin simultaneously with the morning rise of Sirius, i. e., about the middle of July. Unfortunately, I could not find any reference in ancient literature to the period of the prodroms, so that in this case we are obliged to draw our conclusions entirely from our recent anemometric observations. A careful examination of the following quotation from Aristotle shows that in all probability the prodroms were confused with the principal Ornithiens winds:

In the same way, after the time of the winter solstice the ornithiens blow; these winds are weak etesiens; they blow less and later than the etesiens; they begin to blow on the seventieth day because the sun is far away and strengthens them less; they do not blow continually like the etesiens because at that time only the surface frost is melted whereas the deeper frozen parts need more heat. That is why the ornithiens blow intermittently until the summer when the etesiens blow.

There is of course a variation from year to year in the beginning and duration of the etesiens but in general the dates are as indicated above. Indeed, it occasionally happens that the etesiens are replaced by winds of other directions for periods as long as a month.

Table 2, which follows, gives the number of days during which etesiens have blown in Athens during the years 1900–1914, inclusive, and also the distribution of the dates in the 10-day periods of the month.

Prodroms.—According to Table 2 the prodroms blow during the end of May and the beginning of June. They prevail for one or two weeks at most and even then are interrupted by winds of local origin. At the end of the first 10 days of June they give place to the sea breeze or other local winds which prevail until about the middle of July when the real etesiens begin. The end of the prodroms is more abrupt than the beginning and they are the most frequent during the last 10 days of May. The north winds of May are, we would say, rather erratic. For example, in May we had north winds:

(1) During the beginning of the month in 1905 and 1907.

(2) Almost continuously during the whole month in 1909.

(3) At intervals during the month in 1908 and 1911.

(4) During the end of the month in 1904 and 1910.

(5) Not at all during the entire month in 1902 and 1904.

This irregularity of the prodroms justifies our opinion that they are the ornithiens mentioned by the ancients which, according to Aristotle, "blow intermittently until the summer solstice when the etesiens blow."

TABLE 2.—*Actual number of days of etesiens in Athens.*

Year.	May.	June.				July.			August.			September.				October.	Total.
	21–31	1–10	11–20	21–30	1–10	11–20	21–31	1–10	11–20	21–31	1–10	11–20	21–30	1–10		
1900	0	0	1	1	5	6	8	5	5	7	6	4	4	5		57
1901	1	0	0	1	2	3	9	5	7	5	1	2	8	4		48
1902	1	2	0	1	5	6	8	7	4	6	9	3	7	1		60
1903	4	1	0	0	1	5	5	8	8	8	4	4	8	1		57
1904	5	1	4	5	9	9	9	8	7	4	5	4	7	0		77
1905	0	0	0	6	10	5	9	10	10	6	7	6	2	0		71
1906	1	0	2	7	2	4	7	8	7	7	10	3	2	0		60
1907	2	0	1	8	4	0	7	9	7	11	7	10	8	7		81
1908	6	3	6	2	4	5	2	6	2	10	5	6	3	0		60
1909	4	2	1	2	0	7	14	5	6	2	1	3	3	2		49
1910	2	0	0	3	1	0	8	3	7	9	3	5	5	1		47
1911	0	3	1	6	6	5	10	2	4	7	8	3	0	2		57
1912	1	5	3	2	4	4	5	3	4	2	4	1	0	2		41
1913	2	6	2	1	0	0	1	0	5	1	0	1	0	2		21
1914	0	0	0	1	1	2	2	5	4	3	3	4	0	0		25
Mean	1.9	1.5	1.4	3.1	3.6	4.1	6.7	5.6	5.9	5.9	4.9	3.9	3.8	1.8		54.1

Etesiens.—As we have already noted the ancients considered that the beginning of the etesiens occurred about the middle of July, simultaneously with the morning rise of Sirius. The accordance of their conclusion with recent data indicates their observational abilities. The atmospheric condition which gives rise to the etesiens and which we will discuss a little later develops gradually rather than abruptly. About the middle of July it reaches a point where it becomes the prevailing condition. For this reason the etesiens at that time attain their full strength and blow continuously for several days at high velocity and without interruption by local winds.

During the period of development of this atmospheric condition causing the etesiens, these winds are present but without strength and only at intervals. In Athens, for instance, before the middle of July, the etesiens blow during the morning and are replaced in the afternoon by the sea breeze.

Because of this preliminary period we must consider as the date of beginning of the real etesiens not the middle of July but the middle of June when the prodroms stop and a new atmospheric condition favorable to the etesiens begins to develop. The real etesiens, therefore, begin to blow at intervals from the middle of June and gradually accumulate strength until the middle of July when they become the prevailing winds. Their greatest frequency is during the last 10 days of July and all of August. They continue with less frequency during September and are rare in the beginning of October. In July and August they often blow continuously for from 8 to 15 days. During the most favorable years they have been recorded as blowing for 27 or 28 consecutive days.

Mr. Krugler in his valuable study *Die Windverhältnisse im oestlichen Mittelmeer und seinem Randgebieten* (p. 66) states that the etesiens are rare in September. As a matter of fact their frequency during that month, though

[2] The Turks call the prodroms, *keras-meltem*, and the etesiens, *karpooz meltem*. (Keras=cherry, i. e., the fruit which is in season during the time the prodroms blow. Karpooz=watermelon, i. e., the fruit which is plentiful in July and August when the etesiens blow.)

not so high as in July and August, is rather marked. Mr. Krugler notes that the number of days of the etesiens yearly is 33 while actually this number often exceeds 50. The real etesiens cease during the beginning of October. We frequently have during this month, it is true, north winds but neither do they show the characteristic features of the etesiens nor do they arise from the same atmospheric condition. On the open sea as, for example, in the Aegean, the etesiens are more frequent and more regular than in Athens. Very often in the summer months the sea breeze may blow in Athens while the etesiens prevail in the islands of the Aegean reaching Attica 10 miles north of Athens. There are also yearly variations in the etesiens. During some years the entire month of July or August or September is without etesiens and the velocity also is not a constant quantity each year.

Theophrastus writes as follows on this subject:

> Sometimes the etesiens blow strongly and continually and sometimes less and at intervals, because the melting becomes abnormal.

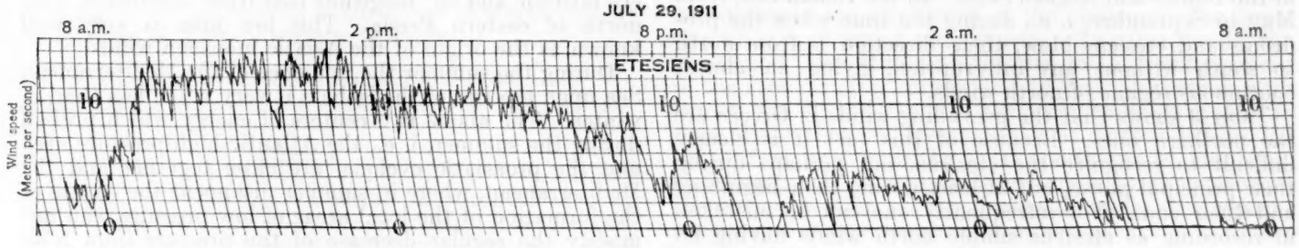


FIG. 1.—Anemocinemographic record from the National Observatory at Athens for July 29, 1911, a day when etesiens were experienced.

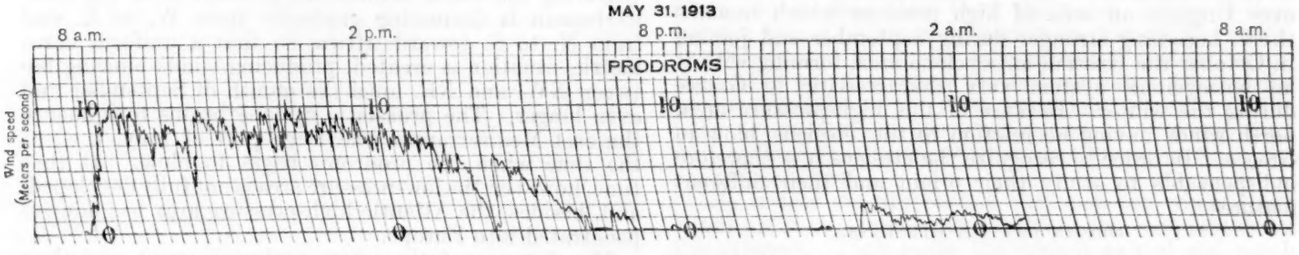


FIG. 2.—Anemocinemographic record from the National Observatory at Athens for May 31, 1913, a day when prodroms were experienced.

Direction of the etesiens.—The difference in the direction of the etesiens in the Aegean and Ionian Seas was noted as early as the time of Aristotle, who wrote as follows:

> The etesiens blow in the west part of the country from N. to W. (W=Zephyros. Zephyros is really a north wind.) During the day the direction of the etesiens is changing, beginning with north in the morning through NW. until in the evening they blow from the west; in the eastern part of the country their direction is between N. to E. as far as Apeliotis (=East).

The direction of the etesiens varies from the Aegean to the Ionian Sea—that is, the etesiens in the west blow from the directions N. to W. and in the east they blow from the directions N. to E.

According to our observations the exact direction of the etesiens is NW. in the Ionian Sea and NE. in the north Aegean Sea. In the southern Aegean Sea the direction becomes north (Naxos, Santorini), and near the northern coasts of Egypt it becomes northwest. This is, of course, the direction in the open sea. At the island of Andros (Aegean Sea), for instance, the prevailing direction is the NW. instead of NE., but this is due to local circumstances. In Athens the direction of the etesiens is NNE. to NE.

Velocity and diurnal oscillation of the etesiens.—From the study of our anemometric data we see that the velocity of these winds undergoes a very distinct diurnal oscillation, analogous to the oscillation of the sea breeze. It is rather strange that the etesiens, although due to general causes, as we shall see later, present very local features, which help to distinguish them from the regular north winds. Their velocity increases almost abruptly in the morning and remains the same with small variations until the afternoon, when it begins to decrease until the night. During the night they almost cease or they blow with a very small velocity.

In Athens the speed of the etesiens during the daytime varies from 5 to 12 meters per second (11–27 miles per hour). During July and August it often reaches 15 m/s. during the time of the highest temperature. In the open sea the velocity is higher. In Athens it very seldom reaches 20 m/s. (45 miles per hour). During 5 consecutive days in 1914 (August 9–13) the etesiens blew in Athens with the speed of storm winds, having a velocity oscillating between 20–21 m/s. (45–47 miles per hour). During the night their velocity was low, as, for example, 6 m/s. on the night of August 9–10. Their maximum velocity occurs during the months of their highest frequency (July and August).

The diurnal change of their velocity was also observed by the ancients. Aristotle writes:

> The etesiens and the prodroms are weaker during the night.
>
> The etesiens blow after the solstice and the morning rising of Sirius, they do not blow when the sun is nearest or when it is farthest away; they blow during the day and cease at night.
>
> Why do the etesiens blow always during the same season and so strongly? And why, when the day ends, do they stop and do not blow at night? Is it because the snow is not melted by the sun in the evening and at night? And they blow fully when the sun begins to melt the northern ice. When the ice begins to melt, the prodroms blow and when it is melted the etesiens.

In the case of the prodroms the velocity is less. It varies between 4 and 8 meters per second (9–18 miles per hour), sometimes reaching 10 meters per second (22½ miles per hour) at the time of the highest temperature. It diminishes in the afternoon and vanishes at night.

The following graphs of the anemocinemograph at the Observatory of Athens give a clear idea of the diurnal variation of the etesiens (Fig. 1) and the prodroms (Fig. 2).

Differences between the Aegean and the Ionian Seas.—A comparative study of the frequency of the etesiens in the Aegean and the Ionian Seas shows that these winds blow simultaneously in both seas. However, the records of the station of the city of Corfu show a marked deficiency which is due to purely local causes. In the case of the prodroms, there exists a difference between the two seas. In the Aegean Sea the prodroms have their greatest frequency toward the last 10 days of May, after which they diminish until about the 10th of June. In the Ionian Sea, the island of Corfu alone has the same distribution as the Aegean Sea. As we go farther south in the Ionian Sea we find a continuous increase in the frequency of north winds from the beginning of May until July and August. In other words, in the records of the southern Ionian stations the separation of prodroms and etesiens is not apparent. Examining the run of the isobars on southeastern Europe and the east Mediterranean Sea, we see immediately that their distribution is quite different in the Ionian and Aegean Seas. In the Ionian Sea, from May to September, i. e., during the time when the prodroms and etesiens blow, their direction is from north to south without any interruption, giving an almost continuous règime of north winds.

Table 3 shows that the prevailing winds in Greece are the northern ones. Because of this fact it is clearly difficult to recognize the etesiens, not perhaps during their principal phase, but at least during their beginning and their end. Not infrequently one can be mistaken in recording as etesiens simple north winds having no relation to the etesiens. During the month of August, when the etesiens reach their maximum, there is formed over Ungaria an area of high pressure which remains there, becoming stronger during September and joining in October the Russian anticyclone area, forming with it an anticyclonic system very characteristic in Greece during the winter. Because of this high-pressure area, north winds having no relation to the etesiens blow in Greece. In order to recognize the etesiens it is therefore indispensable to study their origin and their different features.

TABLE 3.—*Prevailing winds.*

Year.	Athens.	Andros.	Naxos.	Syra.	Santorin.	Chalcis.	Corfu.	Argostoli.	Zante.	Patras.
1900.....	ne.	n.	n.	n.	n.	n.	wnw.	nw.	nw.	n.
1901.....	ne.	nw.	n.	nne.	nnw.	n.	se.	nw.	n.	n.
1902.....	ne.	n.	n.	n.	n.	n.	se.	nw.	nw.	n.
1903.....	ne.	nw.	n.	n.	w.	n.	nw.	nw.	nw.	sw.
1904.....	ne.	nw.	nne.	n.	nne.	n.	se.	nw.	nw.	ne.
1905.....	ne.	nw.	n.	n.	nnw.	n.	se, nw.	nw.	nw.	ne.
1906.....	ne.	nw.	n.	n.	n.	n.	nw.	nw.	nw.	ne.
1907.....	nne.	n.	nne.	n.	n.	n.	nw.	nw.	nw.	n.
1908.....	ne.	n.	n.	n.	n.	n.	ne.	nw.	nw.	ne.
1909.....	ne.	n.	nne.	ne.	w.	n.	w.	nw.	nw.	w.
1910.....	ne.	n.	nne.	ne.	w.	n.	w.	se.	nw.	?
1911.....	ne.	n.	n.	ne.	n.	nnw.	n.	se.	nw.	w.
1912.....	ne.	n.	nne.	n.	w.	nnw, s.	se.	nw.	nw.	w.
1913.....	ne.	n.	nne.	n.	n, w	nnw.	sw, nw.	nw.	nw.	w.
1914.....	ne.	n.	nne.	n.	n, w	n.	s.	nw.	nw.	n.

ORIGIN OF THE ETESIENS.

Distribution of the atmospheric pressure.—In winter the eastern Mediterranean Sea and the surrounding countries are subjected to the influence of two great centers of energy, first the Asiatic high-pressure area and second the Atlantic high-pressure area. The distance between these two areas of high pressure is very great, so that the prevalence of local conditions on the Mediterranean Sea is not uncommon.

During the winter, barometric LOWS are very frequently moving over the Mediterranean from west to east. The velocity of displacement of these low-pressure areas is sometimes so great that it is impossible to compare isobaric charts made 48 hours apart. If considering only the influence of the Asiatic high-pressure area we would expect to have in winter on the Greek peninsula a continuous current of northerly winds, but the mentioned low-pressure areas change the situation entirely; the wind system becomes quite irregular and its study difficult.

In summer the distribution of the pressure undergoes an essential change. The Asiatic high-pressure area still persists, displaced, however, toward the north; it penetrates through the Iberic peninsula into central and southern Europe as far as the Ionian Sea, with a tendency to form a secondary maximum (762 mm.) north of the Grecian peninsula.

The pressure gradually diminishes from −25° to +30° latitude. In Asia, instead of the winter anticyclone, a very deep, low area "the proasiatic cyclone" is formed, having its center (below 748 mm.) located at 30° northern latitude and 65° longitude east from Greenwich, i. e., north of eastern Persia. This low area is very well known as the origin of the Asiatic monsoon winds.

During the summer the influence of the Mediterranean Sea upon the run of the isobars is very much less than in winter. The above two centers of energy which prevail during the summer, i. e., the Atlantic high-pressure area and the proasiatic cyclone, are close together and the Mediterranean, where in summer disappear the causes of the formation of the local areas of low pressure, can not modify the regular decrease of the pressure from NW. to SE.[3]

During the warm months the pressure over the Mediterranean is decreasing gradually from W. to E. and from N. to S. toward Africa, so that a uniform barometric situation is created, producing winds blowing between NW. and NE. until the month of September and even longer. The proasiatic cyclone begins to influence the east Mediterranean the later part of May, i. e., at the time when the prodroms begin to blow. At that time, however, the low-pressure area is not fully developed, and, besides, the Atlantic high-pressure area has not yet penetrated into Europe.

The distance of these two centers is great and their mutual influence on the Mediterranean not very important.

The proasiatic low-pressure area, growing in June, extends toward the north while no appreciable change of the gradient on the Mediterranean is observed. By that time the high temperatures of the summer favor the production of the local winds which prevail during this month. In July the two centers are finally developed and the etesiens become the prevailing winds of the eastern Mediterranean. The proasiatic low-pressure area, the cause of the Indian monsoons, is the cause of the etesiens. In other words, we may say that the etesiens belong to the same cyclonic system as the monsoons. It is true that the Atlantic high-pressure area which penetrates into Europe, and the formation of the secondary high-pressure north of Greece, do reinforce the etesiens but their origin is due to the proasiatic low-pressure center.

Even in May, where there is no influence of the Atlantic high pressure, we notice in Greece the prodroms, signs of the later prevalence of the proasiatic low-pressure area. So, *the etesiens are not local winds, due to limited and local causes;* they belong to the great system of the proasiatic low pressure and are connected with the Indian monsoons.

[3] See Julius von Hann *Die Luftdruckverteilung über Mittel und Süd Europa.*

Variation of the atmospheric pressure. Diurnal variation of the velocity.—The monthly means of the pressure of 65 years' observations in Athens (1839–1903), follows:

	mm.		mm.
January	754.45	July	749.92
February	753.76	August	750.38
March	751.39	September	752.57
April	751.04	October	753.74
May	751.22	November	754.06
June	750.92	December	753.54

As we see from this table, the minimum occurs during the summer. At that time the Atlantic high pressure occupies west Europe, but Greece and the eastern Mediterranean are controlled by the proasiatic low pressure. The above minimum of the barometric pressure coincides with the greatest frequency of the etesiens. During the season of the etesiens the pressure in Greece generally is almost normal. But, if we examine the daily values of it, we find that the pressure increases when they blow and it decreases when they stop. Ordinarily, the days with etesiens are characterized by an increase of the atmospheric pressure.

TABLE 4.—*Mean barometric pressure at Athens Observatory.*

[Height above sea level 33 feet. Mean of observations at 8 hr., 14 hr., and 21 hr.]

Date.	Pressure (reduced to 0°C.).	Date.	Pressure (reduced to 0°C.).
1915.	mm.	1915.	mm.
May 14	748.80	June 10	[1] 750.70
15	750.30	11	[1] 750.97
16	[1] 753.83	12	[1] 751.53
17	[1] 753.33	13	750.63
18	[1] 749.87	14	749.57
19	[1] 749.37	15	749.50
20	748.27	16	749.97
21	748.27	17	[1] 752.40
June 1	751.37	18	752.23
2	[1] 753.50	19	751.37
3	[1] 754.20	July 5	751.17
4	[1] 752.60	6	[1] 752.13
5	[1] 753.23	7	753.27
6	[1] 753.23	8	[1] 753.30
7	754.17	9	[1] 752.80
8	[1] 753.23	10	752.27
9	[1] 750.57		

[1] Indicates days of etesiens.

Table 4 gives an idea of the variation of pressure for Athens. In making the following explanation of this phenomenon we have found especially useful the "Daily Weather Reports of Cairo." The Ægean Sea is found, during May and the summer months, to be under the influence of the proasiatic low-pressure area, and the estesiens blow there almost continually. But in continental Greece and the Ionian Sea the gradient is relatively small. Two causes contribute to reinforce this gradient: (1) *In May* the barometric high-pressure area of Tripoli (North Africa) which often extends toward the northeast and, (2) *in summer* the Atlantic high-pressure area which penetrates into Europe as far as the Danubian countries. These two area of high pressure increase the barometric pressure over Greece a little during the time of the etesiens. Without the existence of these two maxima the etesiens would undoubtedly be weaker and less frequent.

In regard to the diurnal change of the pressure during the days of etesiens, the study of the graphs of the Observatory of Athens shows that there is no appreciable change of the regular double diurnal oscillation.

It was believed that the diurnal change of the velocity was due to the overheating during the day and the cooling during the night of the Lybian Desert (North Africa), which accordingly during the day acts like an aspiration center and during the night stops the flow of the air coming from the north. Although this explanation seems simple, I do not believe it is the correct one.

On the coasts where the sea breeze is observed, a certain time between sunrise and 9 or 10 a. m. is required to establish this aerial current in a radius not exceeding 20 or 30 kilometers. It does not seem reasonable, therefore, to assume that from sunrise until 8.30 or 9 a. m. a strong aerial current may be established between the parallels 39° and 29° N., i. e., covering a distance of more than 1,000 kilometers, the difference of the pressure between the Lybian Desert and Greece being 1 and 2 mm. during the days of etesiens.

The direction of the gradient is west-east. East of Greece, at a distance of almost 220 kilometers, is Asia Minor. The sun, owing to the diurnal revolution of the earth, sets first in Asia Minor and afterward in Greece. The Asiatic Continent, hot during the day time, cools off quickly during the clear summer nights. The result is the diminishing of the gradient between it and Greece, and consequently the weakening of the etesiens. The opposite thing is observed after sunrise. In other words, the location of Asia Minor contributes to the reinforcement of the etesiens after sunrise and to their weakening after sunset, the diurnal range of temperature being greater in Asia Minor than in Greece, which is surrounded by the sea. If at any time the local conditions of humidity, cloudiness, etc., over Asia Minor are such as to prevent the normal cooling process during the night, the etesiens continue to blow even at night almost as strong as during the day.

The meteorological elements during the time of etesiens.—Since the etesiens blow from the north quadrant they become hotter, going more and more toward the south. In Athens and especially in continental Greece, where they have to go through the hot continent they arrive dry, and in spite of the fresh sensation they offer to the body on account of the evaporation, the temperature during the day is mostly higher than the days when the sea breeze blows.

The results are different in the open sea where these winds are really fresh, and moderate the temperature of the summer. They strike the islands as real sea, north winds, fresh and very agreeable, without first being influenced by the land.

TABLE 5.—*Meteorological elements at Athens.*

	Maximum temperature.	Humidity (relative).	8 a. m.–9 p. m., evaporation.	Wind.
1911.	° C.	Per cent.	mm.	
July 19	33.0	42	5.7	Etesiens.
20	30.6	36	6.0	Do.
21	30.6	32	6.4	Do.
22	31.2	34	6.6	Do.
23	30.2	31	6.4	Do.
24	29.2	23	6.0	Do.
25	30.9	30	6.0	Do.
26	32.0	29	6.6	Do.
27	35.0	19	8.0	Do.
28	29.8	32	6.2	Do.
29	29.7	38	4.8	Do.
30	31.1	32	5.2	Do.
31	28.6	43	4.2	Sea breeze.

The dryness of the etesiens and their high temperature give to Athens clear skies and high evaporation. Table 5 gives for Athens the maximum temperature of the days with etesiens, the relative humidity at 2 p. m. (Athens legal time), and the quantity of the evaporated water between 8 a. m. and 9 p. m.

Clear skies is one of the outstanding features of the etesiens. In Greece, where the prevailing winds are the northern ones, one must give close attention in order to discriminate between them and the etesiens.

A consequence of the dryness is the lack of rain when the etesiens blow. Sometimes, but very seldom, the etesiens are accompanied by cloudy sky and bad atmospheric transparency, as in the case of sirocco.

Physiologic influence of the etesiens. Influence upon the vegetation. Importance for navigation.—In spite of the vivifying influence of the etesiens upon the human body, due chiefly to evaporation, they are disagreeable from another point of view, especially in the city of Athens.

Contributing to a great extent to the dryness of the soil, they raise by their motion great quantities of dust. Sometimes when the etesiens blow, Athens disappears in a cloud of dust; plants are covered with dust, and generally it becomes very unattractive to stay in Athens. It is only during the night, when their velocity diminishes and the dust falls, that it is possible to feel their benevolent influence.

Even in the islands the etesiens are not always agreeable. Their velocity is very often so high that it is not at all pleasant to stay out in the open air. Furthermore vegetation suffers very much from the etesiens. Not only are the plants covered with dust but they are violently shaken; flowers and leaves are detached as in autumn. That is why the inhabitants of the Aegean Islands are obliged to take precautions against the etesiens, protecting the orchard trees by rows of cypresses.

The velocity of the etesiens in the Aegean Sea is frequently very high, almost stormy, making navigation very dangerous. It is a well-known fact that at that time boats can not approach the harbors of the Aegean Islands, because of the very rough sea.

These winds descending toward the south from the mountains become violent and dangerous (fall winds). Dangerous places known to navigators are the south coasts of Euboea, the south coasts of the islands Andros, Tinos, and Crete, and the rocky coasts of Maleas (south Peloponnesus).

Ancient history is rich in examples showing clearly the prevailing influence of the etesiens upon the communications and the marine relations of the inhabitants of the Aegean Islands. To-day, also, during the season of the etesiens, sailboats can not go through the Dardanelles and reach the sea of Marmora and the Black Sea. It is not uncommon to see a great number of them (sometimes over 200), waiting at the island Tenedos for a favorable wind in order to enter the Dardanelles.

In antiquity these winds favored colonization, being of appreciable value to communication between Greece and her colonies to the north. During their season it was very easy to transport crops from the agricultural colonies of the Black Sea as far as Greece. But, on the other hand, they prevented the arrival of help sent from Greece to the northern colonies in case of emergency. An enemy like Philip of Macedonia, putting forward his plans rapidly and secretly, found very great help in the etesiens. It was really very dangerous and irksome for the Athenian fleet to sail toward the north, being obliged to use the oars. For this reason the ancient Greeks observed the etesiens and tried to determine as accurately as possible the date of their beginning, their period, their interruptions, etc. The etesiens are not limited to the Aegean and the Ionian Seas. They also blow over the Black and the Marmora Seas and mostly over the Bosporus. They blow continually during four to six weeks, under a clear sky as far as the coasts of North Africa.

Prediction of the etesiens.—In summer, during the season of the etesiens, weather changes in Greece are almost unknown. High temperature, clear skies, dryness, local heat thunderstorms, accompanied sometimes by hail, are the general features of the summer season. As soon as the reinforced proasiatic low-pressure area extends as far as the Grecian Seas, the etesiens begin to blow over the Aegean Sea and the oriental coasts of Greece. These are not very strong and are interrupted by the local winds. Little by little when the high pressure over the Danube countries begins to develop, the etesiens become stronger and steadier. Their prevalence in Greece is preceded by a small, gradual increase in the pressure under a clear sky.

On the Aegean Sea the etesiens blow during almost the whole summer, so that we can say that they do not need to be predicted. Their velocity increases with the pressure and often reaches force 9 of the Beaufort scale, when the sea becomes dangerous even for the largest boats. So far we do not know any particular local signs for predicting the etesiens. Sailors sometimes predict the etesiens from little clouds floating over the tops of the high mountains.

RELATION OF SUNLIGHT TO PLANT DEVELOPMENT.

By GEORGE D. HEARN.

This paper is largely a report on experiments of W. W. Garner and H. A. Allard, plant physiologists of the United States Department of Agriculture, who have made quite complete observations on many different plants under various light conditions during the years 1918 and 1919.[1] Of the three factors entering the study, namely,

a. Intensity of light.
b. Quality of light or wave length of radiation, and
c. Duration of exposure,

the last mentioned is considered chiefly.

Considering *intensity*, it is quite generally agreed there is an optimum for each species which in most cases is less than full sunlight on a clear day. Many plants prefer direct sunlight and others indirect, as ferns, which grow in the shade of forest trees and the alga which is found on the north sides of trees. One effect of the intensity of light upon plants is well brought out when we observe a horizontal branch and a vertical branch on the same tree. On the vertical branch, if we are considering, for instance, a maple tree, the leaves will be four-ranked, i. e., in four vertical rows. The horizontal branch, while having the leaves actually attached in four rows, will have the petioles so twisted that the leaves will appear to be two-ranked, with the surfaces upturned toward the source of light. Plants grown in south windows, the appropriately named sunflower which follows the sun in its daily journey across the sky, and several "compass plants" all illustrate the effect of light intensity. In cross section, the mesophyll or middle layer cells of sun leaves display more chlorophyll bodies than do shade leaves. It is the chlorophyll or green-colored bodies which, under the influence of sunlight are responsible for the manufacture of the carbohydrate foods in plants and also the cellulose or woody material. This fact makes more understandable the blanching of celery and rhubarb and the "laying" or lodging of wheat due to the shading of the lower portions of the stalks resulting in insufficient woody material. In general a plant receiving less than its optimum of light intensity is pale, elongated, and weaker than it would otherwise be.

In regard to the *quality* of light there is not so much uniformity of opinion. White light has in general been found more favorable to plants.

The effect of the duration of *exposure to sunlight* on plants has promoted definite contributions to phenology, especially notable being that of the physiologists already mentioned. The following preliminary observation which acted as an incentive to Garner and Allard is worthy of note. "In 1906 there were observed in a strain of Maryland narrow leaf tobacco, which is a very old variety, several plants which grew to an extraordinary height and produced an abnormally large number of leaves. As these plants showed no signs of blossoming with the advent of cold weather, some of them were transplanted from the field to the greenhouse and the stalks of others were cut off and the stumps replanted in the greenhouse. These roots soon developed new shoots which blossomed and produced seeds, as did also the plants which had been transferred in their entirety. This very interesting giant tobacco, commonly known as Maryland Mammoth, which normally continues to grow till cold weather in the latitude of Washington, D. C., without blossoming, proved to be a very valuable new type for commercial purposes, but the above-mentioned procedure has been the only method by which seed could be obtained. The type bred true from the outset, and no matter how small the seed plant, the progeny have always shown the giant type of growth when propagated under favorable summer conditions."

LENGTH OF DAY AS A FACTOR IN THE NATURAL DISTRIBUTION OF PLANTS.

Heretofore temperature, water, and light-intensity relations have been considered the chief external limiting factors governing the distributions or range of plants. The observations and experiments of Garner and Allard show that the relative lengths of the days and nights during the growing period must also be recognized as among those causes underlying the northward or southward distribution of plants. The equatorial regions of the earth alone enjoy equal days and nights throughout the year, and if water relations are favorable the warm temperatures here favor a continuous growing season for plants. Going to the higher latitudes the favorable growing temperatures are, other things being equal, limited to the summer season, which becomes increasingly shorter as we near the polar regions. On our way to the higher latitudes we find that the summers have increasingly longer periods of daylight and the winters shorter periods. It is interesting to consider how these different day-and-night relations obtaining during the summer, exercise some control upon the northward or southward distribution of plants.

Evidently a plant can not naturally persist in a region or extend its range in any direction unless conditions are favorable, not only for vegetative growth, but for reproduction as well. Seed reproduction alone is considered here. The experiments carried out by the two men already mentioned have brought out the fact that the flowering or reproductive phase of development depends upon a stimulus afforded by the shortening periods of sunlight experienced as the summer solstice is passed. Experiments with ragweed proved that when the length of day fell below 15 hours the vegetative development was checked and the blossoming or reproductive phase induced. It is thought that seeds of plants which blossomed July 1 at Washington, D. C., would not blossom until August 1 in northern Maine, because the day of less than 15 hours would not be experienced until then. If the seed were carried still farther north, the plants might not blossom at all, because the shortest days of the summer-growing period would exceed those to which they were best suited in their normal habitat. Formerly this failure to flower would be attributed to unfavorable temperature alone, but it is obvious that the length of day is the limiting factor which has retarded the reproductive period, so that unfavorable temperature has prevented the ripening of the seed.

No doubt the length of the daylight period in summer has much to do with the vegetative growth and flowering of the Arctic plants. Also, the equal days and nights of the Tropics are required for the successful existence of the indigenous flora.

[1] See Jour. Agr. Research, Mar. 1, 1920, 18:553-606: abstr. in MO. WEATHER REV., July 1920, 48:415. Later note in *Science*, June 2, 1922, 55:582-583.

In a study of the phenological aspects of different species of plants, the fact that there is a definite season for blossoming is brought out. The length of day no doubt is an important influence here. It is probable that plants which blossom when the 12-hour day is reached would become perennials in the Tropics, where the day is never much less than 12 hours.

"Since it has been shown that the stature of some plants increases in proportion to the length of the day to which the plants are exposed under experimental conditions, this factor should be expected to have some influence upon the plants in their normal habitat. In general, exceptional stature would be attained in those regions in which a long-day period allowed the plants to attain their maximum vegetative expression before the shorter days intervened to initiate the reproductive period. This condition should hold true not only for different latitudes where a plant has an extensive northward and southward range, but for different sowings in the same locality at successively later dates during the season. It is a matter of common observation that the rankest-growing individuals among such weeds as the ragweed, pigweed, lamb's quarter, cocklebur, and beggar-ticks, other conditions being equal, are those which germinated earliest in the season, and consequently were afforded the longest favorable period of vegetative activity preceding the final flowering period. It is also a matter of common observation that all these weeds, when germinating very late in the summer and coming at once under the influence of the stimulus of the shortening days, blossom when very small, often at a height of only a few inches."

In studying plants introduced from other regions, in order to determine their economic qualities, the length of day factor must be carefully considered. Dr. H. L. Shantz, plant geographer of the United States Department of Agriculture, recently brought some grasses back from equatorial Africa which in the longer day period of northern Texas attained a height of more than 20 feet, with a corresponding increase in bulk of stalk.

LENGTH OF DAY AS A FACTOR IN CROP YIELDS.

So far as is known, the length of day is the most potent factor in determining the relative proportions between the vegetative and the fruiting parts of many crop plants; and, in fact, fruiting may be completely suppressed by a length of day either too long or too short. In some crop plants the vegetative parts alone are sought, while in others the fruit or seed alone are wanted, and in still others maximum yields of both vegetative and reproductive parts are sought. It is apparent that the merits of the different varieties or strains may depend largely on the relative length of day in which they are grown, and, therefore, the date of planting may easily become the decisive factor. These are matters of vital importance to the plant breeder and the agronomist. Obviously, a delay of even two or three weeks in seeding certain crops because of inclement weather conditions or other considerations may bring about misleading results. It is to be remembered that planting too early may be equally inadvisable, for crops requiring relatively short days for blossoming may thus come under the influence of short days in early spring, resulting in "premature" flowering and a restricted amount of growth.

CONCLUSION.

Seed reproduction can be attained by the plant only when it is exposed to a specifically favorable length of day (the requirements in this particular varying widely with the species and variety), and exposure to a length of day unfavorable to reproduction but favorable to growth tends to produce gigantism or indefinite continuation of vegetative development, while exposure to a length of day favorable alike to seed reproduction and to vegetative development, extends the period of seed reproduction and tends to induce the "ever-bearing" type of fruiting.

The term *photo-period* is suggested to designate the favorable length of day for each organism.

TEMPERATURE OF AIR IN THE ICE CAVERN OF DOBSINA.[1]

By Dr. D. L. STEINER.

[Meteorological Institute, Budapest, Hungary, August 18, 1922.]

The Hungarian Meteorological Institute of Budapest has made, since November, 1911, several years' observations of the temperature in the ice cavern of Dobsina, latitude 20° 18′ 6″ E. (G. M. T.), longitude, 48° 52.2 N., elevation above m. s. l., about 980 m.

A thermograph was placed in an English instrument shelter. The automatic record from this has been regularly compared with a mercurial thermometer alongside of it. In 1912 a hygrograph was installed. Outside, in front of the cavern entrance, another instrument shelter containing a similar thermograph and a mercurial thermometer was erected. With the exception of a few interruptions due to instrumental defects, the data obtained extend to January, 1919. At the end of August, 1917, four thermometers were placed in the rocky wall of the cavern at the following depths: 0.24 m., 0.33 m., 0.44 m., and 1.08 m.

The cavern, the entrance of which faces north, forms a bag stretching downward, having the open end out and with a small aperture in the bottom. The latter leads into the crevices of the rocks. The air of the cavern has access to that outside only by means of the aperture just mentioned together with such small amounts as may pass through the capillary clefts in the rocks.

The chief results of these observations are shown in the table following:

Monthly and annual mean temperatures in the cavern and departures from outside air temperatures. (Degrees C.)

	Jan.	Feb.	Mar.	Apr.	May.	June.
Mean cavern temperature	−3.16	−2.74	−1.80	−0.90	−0.36	−0.10
Difference between cavern and outside air temperatures	+3.62	+0.54	−2.43	−3.88	−7.60	−10.44

	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Mean cavern temperature	+0.07	+0.15	+0.21	+0.09	−0.73	−1.39	−0.89
Difference between cavern and outside air temperatures	−10.65	−11.06	−6.78	−3.39	+0.11	+0.53	−4.37

[1] Abstract from a paper presented at the Hungarian Academy of Sciences, Budapest, Sept. 13, 1922. Meteorol. Zeitschr., 1922, pp. 193–199.

For the temperature of the air in the cavern the following factors are, in general, of decisive importance: (1) When the temperature of the air outside is less than that of the cavern, the external colder and heavier air flows down into the cavern; (2) when the external air is being pushed into the cavern by the wind through the entrance and in much smaller measure through the narrow clefts in the rocks of the mountain; (3) the air which has come into the cavern, when above 0° C., melts the ice in the cavern, whereby it cools down and is only partly active in increasing the temperature of the cavern; (4) the rocky walls of the cavern, cooled to a considerable depth during winter, are acting against the warming of the cavern through the intruding external air during summer.

On the days when the external temperature is less than that of the air in the cavern, a well-pronounced and regular diurnal change of temperature could be observed, the range of which is 0.37° C., mean of the months October–April, and the range in the cavern is, in general, proportional to the range outside; on the days when the air outside is warmer than that in the cavern, this diurnal range is only 0.02° C. The rôle of the temperature differences between cavern and external air can not strictly be separated from the factor (3) of the temperature variation of the cavern, mentioned above, because a positive temperature difference between cavern and external air—the difference taken in the sense cavern-external air—is in general connected with a temperature of the intruding air below 0° C., and a negative difference with an external temperature above 0° C.

The hygrograph in summer invariably traces a straight line; the air in the cavern is saturated. At this time also the temperature of the cavern is almost invariable. The heat of the intruding air is chiefly employed in melting ice, and by the vapor of the ice water the air becomes saturated. In winter, on the contrary, the hygrograph sometimes registers considerable change of the relative humidity and in this respect the following regular features could be stated: When the temperature of the air in the cavern is less than that of the external air, the air in the cavern is saturated or very nearly so; when the temperature in the cavern is higher than outside, the relative humidity decreases and varies according to the amount of vapor contained in the ntruding air as long as the temperature of the air in the cavern has remained less than that of the air outside; at this moment the relative humidity begins to increase and by and by augments until the state of saturation is reached. From the days in the winter half year, on which the temperature in the cavern is higher than outside, the following diurnal change of the relative humidity could be determined:

	A. M.					
Hour	2	4	6	8	10	12
Per cent	+0.23	+0.25	+0.27	+0.24	+0.20	−0.08

	P. M.						Mean.	Range.
Hour	2	4	6	8	10	12		
Per cent	−0.42	−0.48	−0.32	−0.15	+0.06	+0.19	88.79	0.75

The conditions which determine the change of temperature in the cavern are also decisive for the change of the relative humidity.

SEVERE HAILSTORM NEAR WEST CHESTER, PA.[1]

On August 31, 1922, there occurred near West Chester, Pa., a hailstorm of remarkable intensity.

It was reported to this office by Mr. J. T. Brosius, superintendent of the Philadelphia & West Chester Traction Co., from which we quote as follows:

"At 7:30 p. m., about three hours after the storm had ceased, I left the Fair Grounds for Philadelphia. When about 3 miles out I noticed that some fields were still almost entirely covered with hail, which was blown or washed into ridges several inches deep. On the south side of the road there was a bank about 70 feet long with a maximum depth estimated at 3 feet. I had it measured at 10:00 a. m. of the following day and found a maximum depth of 26 inches."

"On September 1, I was informed that there was a great amount of hail washed into the flat part of a field about a quarter of a mile south of West Chester road. I went there about noon, 20 hours after the storm, and found more than an acre of ground entirely covered with hail from a depth of a few inches to more than 2 feet by actual measurement. The average depth was about 1 foot."

[1] Communicated by Geo. H. Bliss, meteorologist, Philadelphia, Pa.

THE CHARLOTTESVILLE, VIRGINIA, TORNADO OF AUGUST 7, 1922.[1]

By ALBERT W. GILES.

"The worst storm in over 30 years!" "The most destructive storm in the memory of the oldest inhabitants!" "The most violent storm this region has ever experienced!" "A regular Kansas twister!" These and similar comments were to be heard on the streets of Charlottesville Tuesday, August 8, 1922.

About 3 o'clock on the previous afternoon the region just west of Charlottesville was swept by a tornado of mild intensity. The day had been hot, with high humidity, and about 2:30 in the afternoon typical "thunder heads" were observed rolling up in the northwestern sky. The storm approached with the rapidity characteristic of its type, the sky becoming black, which turned rapidly to a dark gray and then assumed a copper hue. The usual premonitory gusts were experienced with the wind driving low-lying clouds in several directions. A sharp downpour of rain and hail followed, with intense lightning and thunder. In the midst of this downpour the tornado appeared and disappeared with the roar and rapidity of an express train.

The shower continued for 15 minutes longer. The sky then cleared, but the sunshine lasted for only a few minutes, a gentle rain setting in almost immediately that persisted until nearly 6 o'clock. The sky again cleared and remained clear throughout the night. The next day was as warm and oppressive as the previous one had been, a gentle southwest breeze blowing. A thunderstorm with hail developed again in mid-afternoon. Cooler weather followed on Wednesday.

The tornado developed apparently on the east flank of the Blue Ridge just below the mountain crest, for the first destructive effects were noted 1½ miles east of Crozet. Here the limbs of trees were broken off and small trees overturned. In its eastward sweep, however, the tornado gained quickly in intensity. It leveled a large number of trees in the grove surrounding the church 1 mile west of Mechum. The roof of the Chesapeake & Ohio Railway station at Mechum was removed, as well as a large part of the summer back porch of the home of Mr. Ira A. Beaver, near Mechum. In this neighborhood the trees and growing crops suffered severely.

The tornado lifted just east of Mechum and for a distance of 1½ miles there is little evidence of destruction. Descending again on the farm of Mr. Hugh Sims, 1½ miles west of Ivy, it removed five stacks of hay, blew the chimney from the house, and uprooted and twisted off a number of trees. The tornadic whirl again lifted only to descend with destructive violence on the farm of Mr. H. W. Vandevender at Ivy. A shed 20 by 40 feet was completely demolished, the timbers being carried 300 yards to the east, and the hay that filled the barn was strewn over a large area. Part of the roof of the house was removed, and leaves were blown with such force into the side of the house that they still adhere to the boards (September 12). Over 1,000 trees were blown down on this place, fully half of which were locusts.

The Mackreth farm, adjoining Mr. Vandevender's on the south, was the site of severe destruction, especially to trees. Nearly all the trees around the Shiloh Methodist Church adjacent to the Mackreth place were twisted off or overturned, including an oak 150 years old. The steeple was removed from the Ivy schoolhouse.

Just east of Ivy the chimney was blown from the roof of St. Paul's Church, and an oak in front of the church, 200 years old, was uprooted and overturned, crushing a small touring car which the occupants had just abandoned. At the home of the rector near by nine trees were blown down, but the house miraculously escaped.

The Lewis family was holding a reunion near St. Paul's Church, on the site of "Forest Hill," the name of the plantation settled in colonial times by one of the early members of the family. The place is famous as the birthplace of Meriwether Lewis, who, associated with William Clarke, carried on important explorations in the West in the early part of the last century. Fifteen tents comprising the encampment were leveled, cots were carried across a wire fence into the adjoining cemetery, and suitcases were picked up 200 yards from the camp.

The office building at "Spring Hill," the home of Mr. J. S. Wood near Ivy, was demolished, and a falling tree tore away the porch of the residence.

Just east of Ivy the tornado split, one whirl traveling toward Owensville for a distance of 2 miles and then turning moved eastward crossing the Charlottesville-Owensville road at Ivy Creek. This tornado did little damage, except local destruction of timber and crops.

The second whirl maintained its course east-southeast from Ivy. Striking the home of Mr. Herbert Carey, one-half mile from Ivy, the tornado picked up the roof of the ice house, a building 12 by 16 feet, and rotating it through an angle of 180° in a reported clockwise direction, set it down again upon its foundation. The carriage house just beyond completely collapsed, the roof being turned through an angle of about 90°. In the grove surrounding the house nearly a dozen trees were blown over, one tall locust having been split by a twisting motion and then broken off several feet above the ground. The house was not damaged, due probably to the protective effect of the grove.

The home of Dr. Harry Marshall, three-fourths mile southeast of the Carey place, was damaged slightly, the chimney was blown off and crashed through the porch roof. About 40 trees in the yard of this home were leveled.

Turning to the northeast the tornado crossed the railroad at a point about halfway between Ivy and Woods and descended on "Westleigh," the home of Mr. James Higginson. The implement house, chicken house, and stable shed were unroofed and blown down.

East of "Westleigh" the destructive effects are not so apparent. The tornado passed between Woods and Observatory Mountain and across the campus of the University of Virginia. In this part of its course the damage was less severe, fewer trees were uprooted, overturned, and twisted off, and crops were less affected, though badly damaged.

Although only one person is reported to have seen a funnel-shaped cloud, there can be little question but that this storm should be classed as a tornado. In most places its path was wide, one-half mile or more, hence its energy was dissipated over a considerable area, rather than confined to a narrow belt with the intensely destructive effects and loss of life characteristic of many tornadoes.

The rapid movement of the storm and the roar of its passage are characteristic of tornadoes. Numerous observers report that the storm passed in less than 2 minutes; all of the damage was done in that time. The

[1] The illustrations submitted by Professor Giles have been filed in the Weather Bureau archives, where they may be consulted by those interested in the study of tornadoes in general or in this particular tornado. See also the account by the same author of the tornado of October 28, 1918, this REVIEW 46:460-64.—ED.

rotation of buildings observed in the path of the storm, the transfer of heavy building timbers hundreds of feet, and the twisting off of trees are also tornado characteristics.

No one was injured, although a number had narrow escapes. The chief damage was confined to timber and crops. The corn and fruit crops within the path of the storm were almost entirely destroyed. Locust trees suffered more than any other kind. It has been estimated that half of the trees blown down were locusts. Oaks also suffered severely, a number of oaks destroyed had been landmarks for more than a century.

The following temperature and precipitation records for the date of the storm and the days immediately preceding and following were furnished by Dr. Harold L. Alden of the University of Virginia Observatory. The barometric pressure record was taken from the daily weather map published by the Washington office of the Weather Bureau. The record as reported by the Lynchburg office was used.

Date.	Temperature.		Atmospheric pressure.		Precipitation.	Remarks.
	Maximum.	Minimum.	Lynchburg—8 a. m.	Abnormal change in 12 hours.		
	° F.	° F.				
Sunday, Aug. 6	89	62	30.06	+4	0.61	Heavy hail, thunderstorm.
Monday, Aug. 7	87	66	29.86	−14	0.79	Hail, thunderstorm.
Tuesday, Aug. 8	87	64	29.76	−6	.....	
Wednesday, Aug. 9	77	59	29.96	+4	0.07	
Thursday, Aug. 10	77	62	30.10	+8	.....	

Tornadoes almost universally occur in the southeast quadrants of the cyclonic storms or cyclones, the type of storm that occurs in the United States and gives it nearly all of its precipitation. The weather map for Monday morning, August 7, shows such a storm occupying the region of the Great Lakes, the center of which, marked "low" was a long elliptical trough with axis extending east-northeast and west-southwest. The temperature distribution associated with this storm was rather peculiar, a belt of relatively low temperature occupying the Appalachian region from New York to Alabama.

The weather map for Tuesday shows that the storm had moved northeastward and its axis had shifted to a northeast-southwest direction to form a long linear trough paralleling the Atlantic Coast, Such long linear lows constitute the type of cyclone in which tornadoes frequently develop.

The immediate cause of the tornado was the passing eastward of the relatively cold belt of air that occupied the Appalachian region on Monday morning. This colder air came into conflict with the warm air moving northeastward on the Piedmont and produced a turbulence with vortex form that burrowed downward through the lower layers of air until it reached the surface of the earth as a typical tornado.

It is interesting to note in connection with the description of this tornado that a similar phenomenon occurred August 18, 1904. This tornado followed a path closely parallel to that pursued by the one of recent date. It had its origin in "Pigeon Top," an eastward sloping spur of the Blue Ridge west of Owensville and traveling rapidly eastward passed through Owensville. East of Owensville it turned to the southeast and reached the vicinity of Woods before its energy was dissipated. A funnel-shaped cloud followed by "white smoke" was observed by a number of persons. This tornado was accompanied by extremely heavy precipitation and intense lightning. Hail did a great amount of damage also.

At Owensville the path was one-half mile wide. A number of buildings were leveled and crops were destroyed. Fallen trees blocked the roads for days. Only one person was hurt. She was hit by a window sash that was blown into the room where she was sitting.

TORNADOES IN NEW MEXICO.

The rarity of tornadoes in New Mexico is justification for the printing of the accounts of two small tornadoes which occurred on June 2 and Aug. 4, respectively. The account is furnished by Mr. Chas. E. Linney, meteorologist in charge of the New Mexico Climatological Service.

The tornado of June 2, which occurred near Onava, is described by Mr. Ralph Hicks as being observed at 4 o'clock p. m. and lasting but a few moments. It moved to the southeast, the length of path being unknown. There was some rain, thunder, and lightning but no hail. The day was hot and sultry with the clouds moving very rapidly; a funnel cloud was observed. The damage amounted to about $2,000 and was confined to fences, buildings, and live stock. No lives were lost.

The tornado of August 4 was observed at 2 p. m. at a point about 16 miles southwest of Dedman, Union County. Mr. Lewis Hall, who was caught by the storm, reports that it came from the northwest and moved to the southeast in a path about 3 miles long. It caused a loss close to $5,000 in buildings, crops, fences, and live stock, while Mr. Hall and his wife were seriously hurt. The tornado was accompanied by rain, hail, thunder, and lightning, and a pendant funnel cloud was present.—*A. J. H.*

NOTES, ABSTRACTS, AND REVIEWS.

DISTRIBUTION OF WEATHER INFORMATION AND WARNINGS FOR THE CARIBBEAN SEA.

[Excerpts from Weather Bureau Circular of Sept. 15, 1922.]

The United States Weather Bureau has arranged with the United Fruit Co. to broadcast twice daily, beginning September 15, 1922, special weather bulletins for the benefit of Caribbean shipping from the radio station on one of Swan Islands in the western Caribbean.

The morning bulletin will be in two parts, the first to be broadcast only during the hurricane season—June to November, both inclusive. It will contain weather observations from 10 selected stations throughout the West Indies and on near-by coasts; the second part of the bulletin will contain daily forecasts of wind and weather for the Gulf of Mexico and the Caribbean west of west longitude 73°, and advices and warnings regarding the location and movement of hurricanes in the warm season and "northers" in winter. The night bulletin will be broadcast daily throughout the year and will contain forecasts, advices, and warnings of the same character as contained in the second part of the morning bulletin.

A circular giving the details of the broadcasting may be obtained on application to the Chief of Weather Bureau, Washington, D. C.

A DISTRIBUTIONAL AND ECOLOGICAL STUDY OF MOUNT RANIER, WASH.

By W. P. TAYLOR.

[Author's summary reprinted from *Ecology*, July, 1922, 3:214–236, photo, 3 diagrs.]

1. Mount Rainier is a massive eminence, chiefly basaltic in character, with a warm, humid climate and an extremely heavy snowfall.[1] The climatic conditions result in the formation of numerous glaciers. Differences in precipitation on the different sides of the mountain exercise an important influence on the distribution of its birds, mammals, and plants.

2. The *life zone*, mapped on broad lines with *temperature* as the basic factor, and the *habitat* with its *association*, determined chiefly on *water relations*, are relied on to show the distribution of plant and animal life on the mountain.

3. Four life zones are represented, the Transition, Canadian, Hudsonian, and Artic-Alpine. In general, the Transition zone includes areas in the southeastern part of the park below 3,000 feet; the Canadian, the heavily timbered area between 2,000 and 4,500–5,000 feet; the Hudsonian, the subalpine meadow country between 4,500–5,000 and 6,500 feet; the Artic-Alpine, the region above timber line, 6,500 feet and over.

4. The habitats are roughly divisible into three groups: Those characterized by extreme moisture, including stream, stream border, lake, lake shore, and swamp; those characterized by moderate moisture, including meadow, forest, and burn; and those characterized by deficient moisture or of a rocky type, including alpine ridge, pumice slope, rock slide, and, tentatively, glacier.

5. The White River region, in the northeastern portion of the park, possesses several peculiarities; the upper boundary of the Canadian zone is 500 feet higher in this region than elsewhere in the park; the White River area is noticeably drier than other parts of the park; and there are peculiarities in the fauna and flora of the region.

These peculiarities probably arise partly or largely from differences in climate induced by the topography of the Rainier region as related to the prevailing southwest winds.

6. Depth of snow seems to be more important than effective temperatures, winds, or other factors in causing timber line on Mount Rainier. The usual effects of temperature in determining the altitude of timber line on north and south slopes are minimized, apparently through the pervasive effects of humidity about the mountain.

7. It has been possible to classify tentatively 63 species of mammals and birds (33 mammals, 30 birds) as to direction of ingression; in general the mammals and birds of the higher levels on the mountain are derived from the Cascade Mountains east of Mount Rainier, while those of lower levels are derived from the coast strip to the west. Species ingressing from the east have been more successful in extending their ranges about the mountain than those from the west, probably because of the more uniform environment in the higher zones.

[1] Cf. MO. WEATHER REV., July, 1918, 46 : 327–330, 8 photos.

VARIABILITY VS. UNIFORMITY IN THE TROPICS.

In an article entitled "Variability *vs.* Uniformity in the Tropics," Stephen S. Visher[1] has shown that tropical climates are not as uniform as is commonly thought.

Tables are given contrasting temperature conditions of tropical stations with those of selected stations in the higher latitudes. These show that the seasonal range of temperature is greater in the Tropics than in many coast sections of the temperate zones.

The wind directions and velocities, and especially the annual rainfall are shown to be more variable in the tropics than in the higher latitudes. In view of these facts, the author questions whether it is right to give the impression that tropical climates are extremely uniform.

In connection with the above, it is interesting to note an article in *The Geographical Review*, Vol. VI, No. 3, September, 1918, pp. 240–267, entitled "The Real Temperatures Throughout North and South America," by Mark Jefferson. The facts of the actual temperatures in all America are vividly shown by means of serrated curves showing the succession of daily minimum, maximum, minimum, etc., for the hottest month and the coolest month of a particular year.

These temperature curves, for the 27 stations studied, indicate that regularity, monotonous recurrence of a fairly constant change from warm days to less warm nights, is the characteristic of tropical temperatures, and that changeability, incessant alternation of stimulating spells of heat and cold, characterize most of the temperate zones. Each level in the mountains of the torrid zone is characterized by monotonous repetition of one set of temperature oscillations. It is true that lower temperatures are found at higher altitudes, but without the sudden changes, or contrasts between winter and summer temperatures, that mark the temperate and

[1] *The Scientific Monthly*, Vol. XV, No. 1, July, 1922, pp. 23–35.

polar zones. The night is the winter of the tropics, recurring with very little difference throughout the year.

It is evident from these two papers that, though there is but little change from one day to the next in much of the Tropics, the changes from one period to another may be appreciable.—*R. A. M.*

THE PROBABLE EFFECT OF CLIMATE OF RUSSIAN FAR EAST ON HUMAN LIFE AND ACTIVITY.

By S. NOVAKOVSKY.

[Author's summary reprinted from *Ecology*, July, 1922, 3:181-201, 2 maps, tables.]

The climate of the Russian Far East affects all branches of the economic life and activity of the population. If we divide the Russian Far East into separate economic regions, it will be seen that they fully coincide with the climatic provinces and determine not only the present economic conditions, but the future possibilities as well.

Fishing is one of the principal occupations in the northeastern part of the Russian Far East. The climate influences this activity, not only affecting the catch, but the drying of the fish. The climate factors are dampness, large number of cloudy days, fogs, long winter, freezing of the harbors, strong winds.

Cattle and animal breeding.—In the region of the Chukchi, reindeer breeding is the chief occupation. Among the unfavorable effects of climate are severe and snowy winters and very hot summers. Cattle breeding in the Amur Province is hampered by the following climatic conditions: Heavy summer rains and lack of sunshine, with consequent dearth of nourishing herbs. In the Maritime Provinces mild climate and oceanic winds, the latter driving away mosquitoes, are among the favorable climatic conditions.

Hunting.—Among the indirect climatic influences the character of vegetation which is determined by climate must be marked. The direct influences are species of animals and quality of furs, severity of climate, formation of ice crust, sleet, storms, etc., affecting the migration of animals.

Agriculture.—In the Okhotsk, Kamchatka, Chukotsk regions sharp oscillations of temperature, humidity, fogs, etc., preclude the possibility of agriculture. In the Ussuri and Amur Provinces, where climate is milder, agriculture is considerably developed, permitting even the cultivation of rice.

Customs, houses, and food, especially the latter, are affected by climate. In agricultural regions bread is the chief food; fish and meat, on the other hand, constitute the chief food where fishing and hunting predominate. Among the Chukchi reindeer constitute almost the only food.

The effect of climate upon religious beliefs is seen from the worship of rocks, trees, mountains, elements of wind, rain, thunder, etc.

Health.—The long and severely cold winter which is common over the largest part of the Russian Far East is most trying upon the population. The healthiest region is Ussuri. Okhotsk is the least healthful because of the excess of cloudiness and winds. In the northern parts of the Russian Far East the prolonged darkness, as well as the low temperature, are trying, and in summer fogs and exceeding cloudiness along the coast depress and affect the population. The hot days decrease the appetite and affect the digestive system. Hot and humid climate tends to the development of microorganisms.

Diseases.—Lung diseases are especially common throughout the Russian Far East and occur especially in winter. In the Amur and Maritime Provinces diseases of the stomach, as a result of unripe food, also of the difference between the temperature of the day and night, are common. An indirect climatic cause of diseases is food, as, for example, badly salted animal fat, which causes internal catarrh. In the eastern parts of the Russian Far East humidity accounts for rheumatism. Diseases of eyes, often resulting in total blindness, are very frequent in the north and northeast, and are due to the dazzling cover of snow and to smoke indoors. In the Okhotsk-Kamchatka region psychic and nervous disorders are prominent and occur as a result of the long monotonous winter and absence of bright sunny days.

BIBLIOGRAPHY OF METEOROLOGICAL LITERATURE.

The Royal Meteorological Society has just published a "Bibliography of meteorological literature, No. 1 (32 pp., 9¾ by 6)," covering meteorological literature received from September, 1920, to June, 1921. It was compiled from the bibliography printed quarterly in the journal of the Society, and is arranged in the same way, according to the major divisions of the International Catalogue of Scientific Literature. Each item is numbered, however. In the case of books, a valuable feature is the notation concerning reviews published. Copies may be had at 2 shillings and sixpence from the Society, at 49 Cromwell Road, South Kensington, London, S. W. 7, England.

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C. FITZHUGH TALMAN, Meteorologist in Charge of Library.

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C. F. TALMAN, Meteorologist in Charge of Library.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING AUGUST, 1922.

By HERBERT H. KIMBALL, in Charge, Solar Radiation Investigations.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**:225.

From Table 1 it is seen that direct solar radiation intensities averaged slightly above the normal for August at Washington and very close to normal at Madison and Lincoln. A maximum intensity of 1.40 gram-calories per minute per square centimeter of normal surface measured at Washington at noon on August 22 is within 2 per cent of the August maximum for that station.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged close to the August normal at both Washington and Madison, although at Washington there was a deficiency in every week except one.

Skylight polarization measurements made on eight days at Washington give a mean of 57 per cent with a maximum of 70 per cent on the 22d. These are above average values for August at Washington. At Madison, measurements made on eight days give a mean of 55 per cent with a maximum of 72 per cent on the 25th. The mean is below the average polarization, and the maximum slightly above the average maximum, for August at Madison.

TABLE 1.—*Solar radiation intensities during August, 1922.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance. 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
August 2	14.10			0.50							14.10
4	12.68				0.75						14.10
5	14.60			0.47	0.59						14.10
9	10.21	0.44	0.53	0.68	0.89	1.15					9.47
16	18.59					1.33					17.96
17	17.37	0.74	0.84	0.97	1.11	1.32	1.13	0.97	0.83	0.71	19.23
18	17.37	0.73	0.80	0.87	1.00	1.11		0.97	0.87	0.78	19.23
21	7.57	0.92	1.04	1.14	1.28	1.41	1.23				7.87
22	11.38					1.42	1.23	1.06	0.91	0.81	8.48
23	12.68	0.66	0.75	0.88	1.07	1.29					14.10
29	13.13			0.67	0.88	1.21					15.65
Means		**0.70**	**0.79**	**0.77**	**0.95**	**1.28**	**1.20**	**1.00**	**0.87**	**0.77**	
Departures		+0.07	+0.15	+0.02	+0.03	+0.04	+0.20	+0.16	+0.18	+0.13	

Madison, Wis.

Date.	Sun's zenith distance. 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
August 8	7.57			1.04	1.16						8.81
9	9.14				1.06						12.24
10	9.83					1.29	0.96				11.38
15	14.10				0.80						15.65
18	13.61						1.13				13.13
19	12.24			1.01							13.61
25	9.14			1.10	1.21	1.44	1.19				7.87
26	8.81					1.42					8.81
Means				**1.05**	**1.06**	**1.38**	**1.09**				
Departures				−0.12	−0.02	+0.08	+0.06				

Lincoln, Nebr.

August 8	10.97				0.99	1.28					9.83
10	12.68		0.62	0.76	0.96	1.29					13.13
11	14.10					1.20	0.93	0.72			12.68
14	13.61				0.97	1.25					13.13
15	13.61		0.73	0.87	1.08	1.29					15.65
16	16.79		0.75	0.90	1.09	1.31					15.11
17	12.68		0.78	0.88	1.06	1.26					14.10
19	14.10		0.78	0.93	1.14	1.37	1.13	0.91	0.79	0.69	13.61
23	14.10		0.84	0.98	1.17	1.34	1.04				14.10
24	15.11	0.80	0.88	1.03	1.22						10.21
25	9.47			1.06	1.24	1.41	1.12	0.88			6.02
26	9.47					1.31	1.07	0.88	0.72	0.61	10.97
30	16.20						0.94	0.74	0.61		16.79
31	16.79						1.04	0.83	0.74	0.59	16.79
Means		(**0.80**)	**0.77**	**0.93**	**1.09**	**1.30**	**1.04**	**0.83**	**0.72**	**0.63**	
Departures		−0.09	−0.02	+0.04	+0.02	+0.02	−0.04	−0.06	−0.03	−0.05	

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning—	Average daily radiation. Washington.	Madison.	Lincoln.	Average daily departure for the week. Washington.	Madison.	Lincoln.	Excess or deficiency since first of year. Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
July 30	470	513		−2	+37		−3874	−2294	
Aug. 6	415	433		−46	−27		−4193	−2480	
13	439	505		−2	+59		−4209	−2065	
20	529	371		+109	−54		−3448	−2444	
27	346	447		−62	+43		−3879	−2141	

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

NOTE.—Owing to delay in the receipt of the data from South America, the Calama report will be published in a later issue of the REVIEW.—EDITOR.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was near the normal at land stations on the Atlantic coasts of Canada and the United States, as well as in the British Isles. It was considerably higher than usual in the Bermudas and Azores, and after the 8th the North Atlantic high-pressure area was unusually well developed, as during the last two decades of the month the barometer at Horta ranged from 30.24 to 30.46 inches.

The number of days on which fog was reported was considerably above the normal, especially over the western section of the ocean. In the 5-degree square between latitude 40° to 45° N. and longitude 65° to 70° W. fog was observed on 19 days during the month, and over the Grand Banks on from 8 to 12 days. It was also reported frequently over the eastern part of the steamer lanes, although comparatively rare in the immediate vicinity of the British Isles.

The number of days with winds of gale force in August is ordinarily slightly greater than in July. According to the Pilot Chart, the maximum normal for August is 6 per cent, or about 2 days during the month on which gales can be expected in the 5-degree squares in the eastern section of the ocean, between the 50th and 55th parallels and 15th and 25th meridians. During the month under discussion the number of days on which gales were reported in this locality was about normal, although in the region immediately to the south, as well as off the coast of Nova Scotia, gales occurred somewhat more frequently than usual.

From the 1st to the 4th nearly normal conditions prevailed over the entire ocean, except that on the former date a moderate gale of limited extent and short duration was reported by a vessel in midocean. On the 5th there was a fairly well developed disturbance off the coast of Nova Scotia. Storm log:

British S. S. *Valacia:*

Gale began on the 5th, wind SW. Lowest barometer 29.86 inches at 5 p. m. on the 5th, wind SW., 8, in latitude 41° 11′ N, longitude 55° 28′ W. End on the 6th, wind WNW. Highest force 8; shifts SW.–WNW.

At 2:45 p. m. on the 6th the observer on board the American S. S. *Emergency Aid* reported a large waterspout in latitude 35° N, longitude 68° W. It extended toward the water from the base of mountainous cumulonimbus clouds, describing a part of a circle with the concave side toward the wind and lasted 12 minutes. At 4 p. m. on the same day another spout was observed, which was smaller than the first and only lasted 2 minutes.

On the 8th and 9th there was a moderate disturbance between the 30th and 40th parallels, west of the 60th meridian. Storm log:

French S. S. *Britannia:*

Gale began on the 7th, wind SW. Lowest barometer 29.93 inches at 4 a. m. on the 9th, wind WNW., 7, in latitude 39° N, longitude 66° 20′ W. End, 8 a. m. on the 9th, wind WSW. Highest force 9; shifts S.–WSW.

On the 10th and 11th waterspouts were again observed as shown by following reports.

American S. S. *Charles Pratt:*

August 10, 6 p. m. in latitude 31° 10′ N, longitude 79° 10′ W, at the turn of the Gulf Stream to the NE. came into close proximity to 10 large waterspouts. They were traveling in a line North and South and about a quarter of a mile apart. Wind at the time of this formation NW, very heavy nimbus clouds. As the ship was only about a quarter of a mile away it was plainly seen how the water was taken up. Under each spout was formed a large hollow where the water swirled around left handed and with great rapidity. This left handed circular motion continued into the cloud. Photographs were taken. Wind changed to NE. and they were broken up. Heavy rain followed.

American S. S. *Shenandoah:*

At 4:30 a. m. August 11, a heavy waterspout passed about 1 mile astern of the ship in a southeasterly direction, then turned about ENE. and finally disappeared in a heavy rain squall. Greenwich mean noon position on the 11th, latitude 23° 30′ N., longitude 88° 32′ W.

From the 10th to the 14th moderate weather prevailed over the entire ocean, although the Northeast trades appeared to be considerably stronger than usual, especially in the vicinity of the Canaries. From the 15th to 18th there was a disturbance of varying intensity over the middle section of the steamer lanes. Storm logs:

Swedish S. S. *Carlsholm:*

Gale began on the 15th, wind SW. Lowest barometer 29.73 inches at 9 a. m. on the 18th, wind WNW., 8, in latitude 52° 20′ N., longitude 41° 02′ W. End on the 19th, wind W. Highest force 11, WSW.; shifts WNW.–W.

American S. S. *Sapinero:*

Gale began on the 15th, wind SW. Lowest barometer 29.80 inches at noon on the 16th, wind NW., 7, in latitude 49° 08′ N., longitude 16° 47′ W. End on the 19th, wind NW. Highest force 8; steady from NW.

On the 21st the American S. S. *Limon* encountered a northerly gale off the coast of northern Florida. Daily journal:

21st. Day begins fine. 10 a. m. began to blow hard from north. Noon increased to force of 8 with very heavy sea. 2 p. m. wind hauled to the NE. Greenwich mean noon position, latitude 28° 53′ N., longitude 79° 42′ W.

From the 20th to the 22d a number of vessels reported heavy weather over the region between the 40th parallel and the south coast of Newfoundland. Storm logs:

German S. S. *Hansa:*

Gale began on the 20th, wind S. Lowest barometer 29.56 inches at 8 p. m. on the 20th, wind S., 10, in latitude 41° N., longitude 63° 08′ W. End on the 20th, wind NW. Highest force 10, S.; shifts S.–SW.–W.

Dutch S. S. *Veendijk:*

Gale began on the 20th, wind S. Lowest barometer 29.30 inches at 9 p. m. on the 20th, wind SSW., 9, in latitude 41° 44′ N., longitude 62° W. End on the 20th, wind WNW. Highest force 9; shifts S.–SSW.–WNW.

American S. S. *Mongolia:*

Gale began at 6 p. m. on the 20th, wind WSW. Lowest barometer 29.52 inches at 10 p. m. on the 20th, wind W., 8, in latitide 40° 52′ N., longitude 62° 49′ W. End on the 21st, wind WNW. Highest force 8, W., shifts WSW.–W.

British S. S. *Verentia:*

Gale began on the 20th, wind S. Lowest barometer 29.68 inches at 8 a. m. on the 21st, wind SW., 7, in latitude 40° 03′ N., longitude 55° 26′ W. End on the 22d, wind WNW. Highest force 8, SW., shifts SW.–WSW.

At 2:30 p. m. on the 22d the observer on board the American S. S. *Minnequa* sighted a large waterspout in front of a passing rain squall.

On the 23d there was a low-pressure area over the North Sea and northerly winds of gale force were reported from land stations in the British Isles, as well as from the Danish S. S. *Dania*, as follows:

Gale began on the 23d, wind WNW. Lowest barometer 29.82 inches at 6 p. m. on the 23d, wind WNW., 7, in latitude 53° 46′ N., longitude 26° 50′ W. End on the 24th, wind N., 6. Highest force 10; shifts WNW.–NW.

On the 24th vessels in the northern steamer lanes experienced NW. winds of gale force. Storm logs:

British S. S. *Vardulia:*

Gale began on the 24th, wind SW. Lowest barometer 29.73 inches at 9 a. m. on the 24th, wind SW., 7, in latitude 50° 42′ N., longitude 44° 38′ W. End on the 25th, wind NW. Highest force 8; shifts SW.–NW.

British S. S. *Ilford:*

Gale began on the 24th, wind NW. Lowest barometer 29.59 inches at 8 a. m. on the 24th, wind NW., 8, in latitude 54° 45′ N., longitude 21° 45′ W. End on the 27th, wind NW. Highest force 8; shifts W.–NW.–N.–SW.

Charts VIII and IX show the conditions on August 25 and 26, respectively, when stormy weather prevailed over the eastern section of the steamer lanes. Storm logs:

British S. S. *Manchester Spinner:*

Gale began on the 24th, wind NW. Lowest barometer 30.02 inches at 3 a. m. on the 25th, wind NNW., 7, in latitude 48° 32′ N., longitude 37° 39′ W. End on the 25th, wind N. Highest force 7, steady NNW.

British S. S. *Belgian:*

Gale began on the 26th, wind NNW. Lowest barometer 30.04 inches at 10.16 a. m. on the 26th, wind NNW., 7, in latitude 49° 03′ N., longitude 26° 04′ W. End on the 26th, wind N. Highest force 7, steady NNW.

American S. S. *Bayon Chico:*

Gale began on the 26th, wind WSW. Lowest barometer 29.79 inches at 2 a. m. on the 27th wind WNW., 9, in latitude 50° 25′ N., longitude 16° 24′ W. End on the 27th, wind N. Highest force 9; shifts WSW.–WNW.

In the afternoon of the 27th, while off the west coast of Cuba, the American S. S. *Hibueras* encountered a SE. wind, force 7, with rough sea, heavy SSE. swell, and frequent heavy rain squalls.

The observer on board the Danish S. S. *Dania* observed an unusually brilliant aurora borealis off the north coast of Scotland on the 27th, that was visible from 8 to 9:30 p. m. when fog shut in.

On the 28th and 29th stormy weather prevailed over the eastern section of the ocean north of the 40th parallel. Storm logs:

British S. S. *Rathlin Head:*

Gale began on the 29th, wind NW. Lowest barometer 29.77 inches at 4 p. m. on the 29th, wind NW., 7, in latitude 50° 23′ N., longitude 24° 35′ W. End on the 30th, wind NW. Highest force 8, NNW.; shifts NW.–NNW.

British S. S. *Norfolk Range:*

Gale began on the 28th, wind S. Lowest barometer 29.17 inches at 8:50 a. m. on the 29th, wind NW., 7, in latitude 46° 42′ N., longitude 39° 26′ W. End on the 30th, wind NW. Highest force 8, shifts S.–W.–NW.

Japanese S. S. *Choyo Maru:*

Gale began on the 30th, wind NW. Lowest barometer 29.74 inches at 6 a. m. on the 30th, wind N., 8, in latitude 47° 05′ N., longitude 19° 40′ W. End on the 30th, wind NNW. Highest force 8; steady N.

On the evening of the 31st the American S. S. *Coaxet* encountered a sudden squall near latitude 42° N., longitude 43° W. Report follows:

9 to 10 p. m. August 31. Very heavy squall, thick, rain. Wind previously SSW., 6; light cumulus clouds from SSW. Squall came from W. (true) in arch formation similar to China Sea. Wind W., 8, backing to SW., 6 and clearing in an hour, then conditions as before.

NORTH PACIFIC OCEAN.

By WILLIS E. HURD.

The one occurrence of deep interest drawn from the records of the weather over the North Pacific Ocean during August—one that will be remembered in history on account of the disaster it occasioned—was that of the so-called Swatow typhoon. This storm was first observed as a slight depression in the neighborhood of the Caroline Islands on the 27th of July. During the following four days the depression, gradually gaining in intensity, moved west-northwestward, until on the 31st it was over extreme northern Luzon, whence it took a more northerly turn and entered the Chinese coast at Swatow on the night of August 2–3. The enormous tidal wave accompanying the storm crossed the mud flats before the city and in conjunction with the hurricane wind caused a loss finally estimated at upwards of 50,000 lives out of a population of some 65,000 to the unfortunate city.

The following interesting narration concerning this storm was received by the Weather Bureau from the second officer, D. Lammers van Toorenburg, of the Dutch S. S. *Van Overstraten:*

PARTICULARS ABOUT THE TYPHOON OF JULY 31 TO AUGUST 3, 1922.

On the 31st of July a typhoon was signaled within 60 miles of 17° N. and 124° E. moving westward, while on the 1st of August the typhoon appeared to be within 60 miles of 18° N. and 122° E. moving WNW. S. S. *Van Overstraten* was laying at Hongkong, and being bound for Amoy, awaited on the 2d of August for the typhoon warning to be changed. The red cone (local warning No. 1) was up and at 10 a. m. the typhoon appeared to be at 22° N. 118° E. moving NW., while another report said that the center was about 23° N. and 117° 10′ E., moving NW. and threatening Swatow. In the afternoon at about 2 p. m. the local signal No. 1 was lowered and S. S. *Van Overstraten* started on her voyage. As soon as the ship came outside the harbor we felt a heavy and long swell from the ESE., while the sea was smooth and the clouds were slowly working up from the south.

The wind was NW., force 4–5 (Sc. of Beauf.), and the barometer showed a heavy fall. At 12 noon the mercury barometer was 743.3; at 4 o'clock, 745.1. The barometer kept falling till about midnight, when the barograph showed a nearly vertical line. The wind had increased considerably and was gradually turning to the south. As this steady fall showed that the ship was moving towards the center of the typhoon and the sky had a most threatening aspect, the captain turned the ship on her trail and, heading westward, the barometer stopped falling and showed a slight inclination to rise. This was a good sign. The sea was very rough by this time and heavy rollers continually shook the ship in all her beams. The wind had increased to hurricane force, while the rain was pouring down, and heavy gales made matters worse. Anyhow, as the wind showed about 3 a. m. that the center was passed, we returned to the old course, east. In the morning, between 3 and 10 a. m., the rain was heaviest and big seas made it impossible to keep to the course. So the ship heaved to, and it was not until about 9 a. m. that the course east could be followed again. Though the rain kept falling during the whole morning and afternoon, the weather cleared up considerably and also the sea diminished. Around the whole horizon a thick veil of rain had settled, and it was impossible to get any bearings, which condition caused uneasiness. Arrived that night at Amoy, where it was stated that the weather had been very bad the last 36 hours.

The next day we heard that the typhoon was north of Canton City and apparently filling up.

The S. S. *Astuba Maru* wired that she met the typhoon at 22° 5′ N. and 115° 26′ E. moving WNW. This is about the same position we were in at that time, and the above wire should be considered to be a little too rash, as we only struck the outside of the lower semicircle. The typhoon barometer showed the ship to be in the vicinity of about 60 miles.

On arriving at Hongkong we heard that big damage was done to Swatow and about 5,000 people perished.

A preliminary report of the typhoon[1] has been forwarded by Capt. G. St. M. Stocker, of the pilot station on Double Island, in the Han River, a short distance below Swatow, which itself is but 5 miles from the river's mouth. He says:

August 2. Cloudy and threatening with variable light airs till 2:30 p. m. (local time), then moderate to strong NE. breeze, increasing

[1] A further account of this storm may be found elsewhere in this issue of the REVIEW.

until by 10 p. m. full gale from the north, and by 11 p. m. hurricane from the north, fierce squalls. No apparent change in direction till midnight, when wind backed slowly to NNW., force 11–12, and by 1:30 a. m. was NW. A tidal wave, rising about 8 feet above H. W. O. S. swept in from south, subsiding at about 2:15 a. m. From 1:30 to 2 a. m. on 3d a lull occurred, wind veering rapidly through NE. to SE., force 4–7, and at 2:30 a. m. came away from south with cyclonic force, lasting till about 5 a. m., and then blowing from SSE., force 4–6, all day.

Capt. Stocker also observed:

Heavy swell apparent on Swatow bar from evening of August 1, rapidly increasing. About 6:45 p. m. to 7:10 p. m., on August 2, entire atmosphere, but not sky, most distinct yellow tinge, observed and commented on by all residents of island, while sky continued gloomy and lowering, with masses of fracto-nimbus all over.

He also remarked that a more detailed account of the typhoon is under preparation.

The American S. S. *Nanking*, Capt. A. T. Dobson, Shanghai to Hongkong, encountered the outer winds of this typhoon during the 2d and 3d. While the storm center was about at the southern entrance to the Formosa Channel, the *Nanking* on the 2d was keeping well at the northern entrance, with first an ENE. wind, force 7, at 2 a. m., followed at 2 p. m. by a gale, force 9, from the east. This had worked into E. by S., force 9, at 4 p. m. At 5 p. m., in about latitude 25° 40′ N., longitude 121° E., the ship's barometer recorded the lowest pressure, 29.20 inches (corrected). During the southward passage of the channel the vessel encountered mostly S. to SE. winds, and with slowly rising barometer passed Swatow shortly in the rear of the storm center.

The Japanese Weather Report for the week ended August 5 indicates that scarcely had this disturbance ceased to be felt at sea than another was discovered approaching the Loochoo Islands from the eastward. This formed on the 3d near 26° N., 135° E., and on the 6th entered the coast near 30° N. Nothing is known of the storm's severity beyond the fact that it gave rains and strong gales over the Loochoos.

On the 9th of the month a third tropical disturbance originated apparently near the southeastern extremity of Taiwan, moving northeastward. Near 25° N., 126° E., it began to recurve and on the 12th or 13th hit the coast near the 30th parallel, as had its predecessor. On this date the Canadian S. S. *Canadian Prospector*, Capt. Charles Wallace, Vancouver to Shanghai, was hit by the northern edge of the storm, and experienced ENE. to ESE. gales, force 8 to 10, in 31° 05′ N., 122° 10′ E. Her lowest recorded pressure was 29.38 inches at 8 p. m. The observer, Second Officer Mr. J. Addison, wrote:

August 12. Received typhoon warnings from Shanghai that pilot boat would not be able to proceed to sea that day.
August 13. Typhoon swept the China coast. Required to heave to for two days at entrance to Yangtse Kiang.
August 14. Weather cleared and pilot boarded.

Wireless advices of the same storm were received early on the 10th by the Dutch S. S. *Arakan* when near 28° N., 124° 37′ E.: "Typhoon 23° N., 128° E., direction NW." Since the highest force of wind noted by this vessel was 7 from ESE., the observer, P. Bubberman, concluded truly that the "typhoon had passed at a great distance behind us."

At least two other tropical storms, of little known intensity at this writing, are known to have occurred in Far Eastern waters during August.[2] One originated near Guam on the 11th and moved northward, passing near the Bonin Islands about the 13th. Its entire course was well out at sea, and it apparently became an extratropical storm, disappearing, or losing its identity, to the northward of the Aleutian Islands. The other originated on or near the 19th in the Marianas, and after pursuing a north-northwesterly course, crossed Japan near the 35th parallel on the 23d and entered the mainland south of Vladivostock a day or two later. The American S. S. *Nanking* experienced moderate to fresh gales from the southward and westward sides of this storm on the 23d and 24th. Her lowest recorded pressure was 29.12 inches at 8 p. m. of the 23d, while in latitude 30° N., longitude 135° 15′ E.

For the month, as a whole, pressure conditions over the eastern part of the ocean were devoid of any unusual features. At Dutch Harbor, where pressure had been considerably above normal during the last three weeks of July, it fell to below normal at the beginning of August and continued so generally until the last week, when there was a change to above normal conditions. The average of the p. m. readings was 29.83 inches, or some 0.05 inch below normal. The highest reading, 30.16, occurred on the 17th and the lowest, 29.22, on the 23d. The normal pressure at Dutch Harbor falls sharply during August, being approximately 29.97 at the beginning of the month and 29.80 at the end.

At Midway Island p. m. pressure averaged 30.04 inches, or about 0.02 inch below normal. The highest reading, 30.14, occurred on the 7th; the lowest, 29.84, on the 26th. At Honolulu pressure averaged slightly above normal, the plus departure being about 0.02 inch. The highest reading, 30.08, occurred on the 1st; the lowest, 29.95, on the 25th.

The eastern half of the Pacific, by comparison with the western, was calm, indeed. The great North Pacific high-pressure area was persistent over a huge area throughout the month, and was crossed by no depressions. The Aleutian low-pressure area was well developed, and that, or offshoots from it, further covered part or all of the Gulf of Alaska from the 8th to the 14th; the 17th and 18th; and the 29th–30th. On the 28th high pressure came in over the upper reaches of Bering Sea, and spreading southward and eastward, gradually dominated the entire Aleutian area, so that on the 31st the center of the Gulf of Alaska low-pressure area of the preceding date had moved far into the Canadian Northwest.

In Mexican waters few gales were reported. However, the rainy season did not progress throughout the month with entire quiet. On the afternoon of the 27th what was apparently a cordonazo, or hurricane of this region, was encountered by the American S. S. *Henry D. Whiton*, Capt. Rene Blaustein, Observer Robert W. Smith, in latitude 15° 43′ N., longitude 100° 30′ W. At 6:30 p. m. the wind was ESE., force 11, with a barometric pressure of 29.31 inches (uncorrected). At 7 p. m. the wind went into SE., force 10, pressure rising rapidly, and wind thence diminishing from SE. The duration of the gale winds was about five hours.

Waterspouts were observed on two days in these waters. The American S. S. *Minnesotan* saw one at 4:50 p. m. of the 18th in 18° 52′ N., 104° 30′ W., and the second was noted on the 19th by the French S. S. *Alaska*, moving ENE. in 15° 46′ N., 98° 26′ W. The weather was reported as thundery in both instances.

Much fog was recorded over the northern steamship routes. To the west of the 180th meridian, "dense fog" and "continuous fog banks" occurred from the 5th to the 17th; and east of the meridian reports indicate a considerable occurrence of the phenomenon from the 4th to the end of the month.

[2] See article by Rev. José Coronas, S. J., elsewhere in this issue.

THE SWATOW TYPHOON OF AUGUST, 1922.

The Weather Bureau has received the following letter and report concerning the disastrous typhoon at Swatow in August of this year from Capt. G. St. M. Stocker, of the Swatow Pilotage Association. Captain Stocker has been acting as cooperative observer, and the location of his station near the mouth of the Han River enabled him to furnish an invaluable series of observations, but only made under the most trying conditions. Additional remarks by Captain Stocker will be found elsewhere.[1]

AUGUST 29, 1922.

To the CHIEF OF THE UNITED STATES WEATHER BUREAU,
Department of Agriculture, Washington, D. C.

SIR: Please receive herewith a copy of a barograph record taken from my instrument at Double Island, at the entrance to the port of Swatow, in the first week of this month.

Such observations as I was enabled to take prior to and during the storm have been compiled in the form of notes, and I send you these also in the hope that they may prove of some service to you.

You will appreciate the fact that in such a heavy storm, attended as this was by enormous destruction of life and property, it is exceedingly difficult for an observer (whose house is crumbling away piecemeal all around him) to take accurate observations of the true direction of the wind, but I was able to record the barometer regularly and accurately, so these readings may be accepted as fairly correct.

People in Swatow, only 4 miles west of me, agree that they experienced a period of calm, whereas I and others here only experienced a lull, commencing at about 1:45 a. m., the time of the minimum reading of the barometer, and lasting for some three-quarters of an hour, during which time the wind veered from north to south by way of east with varying force between 3 and 8, when, settling from south, it blew by 3:00 a. m. with force 12.

When all the data necessary have been received by you I would esteem it a favor if you would let me have a tracing of the track of this storm, showing various directions and forces of winds at various points simultaneously, with corresponding barometer readings.

I am, Sir, very truly yours,

G. ST. M. STOCKER.

REPORT ON THE SWATOW TYPHOON.

A storm, accompanied by a tidal wave, passed over Swatow and neighborhood on the 2d of August, 1922, devastating a large part of the Han River delta and taking a heavy toll of life and property.

Apart from such telegraphic reports of the existence of a storm to the eastward of the Balintang Channel as came to hand, it was evident to observers on Double Island, at the entrance to the port of Swatow, as early as the evening of July 29 that a depression was moving toward the coast of China, the barometer being rather low and there being a pronounced swell on the bar.

By the morning of August 2 this swell had increased perceptibly, though there was but little wind. The sky was overcast and gloomy and the atmosphere oppressive, light showers falling occasionally.

Calms and variable light airs were experienced till noon, and then the wind came away from the northeast, force 4–6, with heavy showers. The swell on the bar became very heavy and the sea outside turbulent.

Just after sunset the whole sky and atmosphere assumed a dark yellow hue for about half an hour, which was commented on by many.

The barometer readings noted in this report are subject to a correction of +0.15 inch, the last comparison having been made on March 4, 5, 6, 1922. The time on the barograph record is one hour slower than local standard time, i. e., 120th meridian time. The readings recorded here are those of the aneroid, not the barograph.

By 8:00 p. m. on the evening of the 2d the aneroid read 29.20 inches, wind NE., force 6–8, sky Nimbus, 10.

After 8 o'clock the wind slowly backed to north, increasing in force to 10, and so continued till about 1:45 a. m. on August 3.

Shortly before 1 o'clock on the morning of August 3, it was noticed that the water was much higher than normal, and by 2 o'clock it had risen to a height of about 8 feet above normal high water.

From 11:00 p. m. to 1:00 a. m. the barometer dropped each half hour as follows: 0.13 inch, 0.15 inch, 0.35 inch, 0.45 inch. After that the drop was slower, being as follows: 0.15 inch, 0.10 inch, and by 1:45 a. m. it had reached its minimum of 27.55 inches.

After 1:45 a. m. the barometer rose rapidly, the wind veering from north to NE., force 3–6, and at 2:00 a. m. the barometer read 27.85 inches, the wind continuing to veer to the southward and increasing. At 2:30 a. m. the barometer read 28.10 inches, wind SE., force 5–8, and at 3:00 a. m. it read 28.60 inches, wind south, force 12.

[1] See article, North Pacific Ocean.

The wind continued from the south with hurricane force till about 4:30 a. m., the barometer rising rapidly, until by 5:00 a. m. it had reached 29.40 inches, and the wind had dropped since 4:30 to force 5–7.

Both foreign and native shipping suffered heavily. Houses that escaped being blown down were washed away by the waters which spread over the whole country side, and the loss of life was enormous.

Owing to the general inundation, as well as to the extremely heavy rainfall which accompanied the storm, it was several days before the country became drained off, and meanwhile the tides appeared to lose their rise and fall, the surface current flowing to seaward nearly all the time, and the general level remaining above normal.

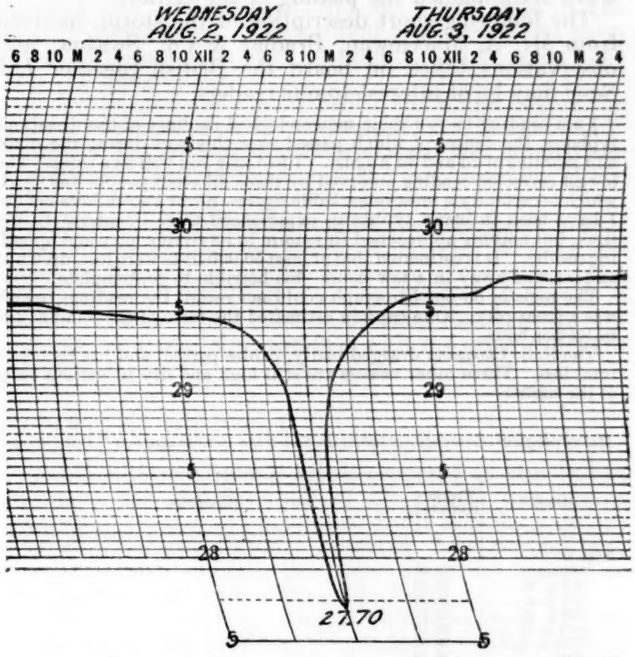


Fig. 1. Copy of barograph trace, extended, during passage of Swatow typhoon. Office Swatow Pilotage Association, Double Island, about 4 miles below city.

TEN DEPRESSIONS OR TYPHOONS IN THE FAR EAST DURING THE MONTH OF AUGUST, 1922.

By Rev. JOSÉ CORONAS, S. J.

(Weather Bureau, Manila, P. I.)

August has been a very stormy month for the Far East. There have been at least five well-developed typhoons, while lack of observations makes it impossible for the present to decide whether the other five atmospheric disturbances shown in our Weather Maps were also, at least for some time, real typical typhoons, or only depressions of less importance.

The Swatow typhoon.—This will go down to history as one of the worst, if not the worst typhoon, that has ever visited the Far East. Our weather map of 2 p. m., July 29, showed clearly this typhoon as situated over 300 miles to the east of central Luzon, although observations from Guam and Yap seem to point out as the probable and approximate origin of the typhoon 138° longitude E. and 14° latitude N. on July 27.

The position of the center at 6 a. m. of July 30 to August 2 was as follows:

July 30, 6 a. m., 128° 25′ longitude E. 16° 00′ latitude N.
July 31, 6 a. m., 125° 40′ longitude E. 16° 50′ latitude N.
August 1, 6 a. m., 122° 45′ longitude E. 18° 25′ latitude N.
August 2, 6 a. m., 119° 30′ longitude E. 21° 05′ latitude N.

The typhoon moved WNW. up to August 31, but fortunately for the Philippines it inclined gradually northwestward on August 31, thus crossing the Archipelago through the Babuyanes, a group of islands whose population is rather insignificant, and from which no information on the storm has been received as yet in Manila by the end of August. From August 1 the typhoon was moving NW. headed for Swatow. The barometers fell there to 27.53 inches at 1:30 a. m. of August 3, dead calm was observed, and a terrific tidal wave accompanied the passing of the center.

The following short description of the storm, received from Mr. A. MacGowan, Bradley & Co., Swatow, and observations taken on board the British Steamer *Lok Sang* may be of interest to our readers.

I am sending to you some meteorological readings of the disastrous typhoon, the center of which passed over this port during the night and morning of 2d and 3d August. I feel sure you will like these. The lowest corrected reading observed by three different people was 27.53, which is certainly a most remarkable figure—never known here before. I have been in many typhoons, experienced three "centers" in my time, but nothing approached this storm in its terrific force and appalling results. It is estimated that at least 50,000 lives were lost, drowned and washed away in a few hours—too horrible to contemplate.

The register on our barograph could not record the readings, which was a great pity. One captain estimated the force of the wind at 100 miles per hour.

The S. S. *Choysang* dragged badly, cables parted, and has become a total loss. Three other vessels are still high and dry in various parts of the harbor.

Meteorological observations taken on board the British steamer "Lok Sang."

Date.	Pressure corrected.	Remarks.
Aug. 1:		
Noon	29.40	
2:00 p. m.	29.40	
4:00 p. m.	29.30	
6:00 p. m.	29.27	
8:00 p. m.	29.30	
10:00 p. m.	29.32	
Mdt.	29.30	
Aug. 2:		
2:00 a. m.	29.30	
4:00 a. m.	29.25	
6:00 a. m.	29.27	
8:00 a. m.	29.25	Light NW. winds.
10:00 a. m.	29.25	
Noon	29.25	
2:00 p. m.	29.20	
4:00 p. m.	29.20	1:00 p. m. Heavy squall. Wind veered to E.
6:00 p. m.	29.15	
8:00 p. m.	29.05	
9:00 p. m.	29.00	Wind increasing in force from NE.
10:00 p. m.	28.90	
10:30 p. m.	28.80	
11:00 p. m.	28.70	
11:30 p. m.	28.55	Heavy squalls from NE. with very short intervals.
Mdt.	28.50	
Aug. 3:		
0:30 a. m.	28.20	
1:00 a. m.	27.75	Blinding rain and continuous NE. winds of hurricane force.
1:30 a. m.	27.53	
Approximately 1 hour lull when wind came away from SW. with increased force. Tidal wave commenced to rise at 11.30 p. m. and rose to 12 feet above H. W. O. S. T. and commenced falling after the center passed.		
2:00 a. m.	27.80	
2:30 a. m.	28.10	
3:00 a. m.	28.50	
3:30 a. m.	28.60	
4:00 a. m.	28.95	Squalls abating at 4:30 a. m.
5:00 a. m.	29.10	
6:00 a. m.	29.15	
8:00 a. m.	29.25	
10:00 a. m.	29.35	
Noon	29.45	

Three severe typhoons and three depressions or ordinary typhoons across the Eastern Sea.—The first of these typhoons appeared on the 4th east of the Loochoos in about 134° longitude E. and 26° latitude N. It moved W. by N. across the Loochoos and the Eastern Sea, and entered China south of Shanghai during the night of the 6th. The approximate positions of the center at 6 a. m. of the 5th, 6th, and 7th were:

August 5, 6 a. m., 129° 15′ longitude E., 26° 55′ latitude N.
August 6, 6 a. m., 125° 00′ longitude E., 28° 05′ latitude N.
August 7, 6 a. m., 120° 00′ longitude E., 29° 55′ latitude N.

The S. S. *Karachi Maru* being in 125° longitude E., 28° latitude N., reported a barometric minimum as low as 737.1 mm. (29.02 ins.) at 6 a. m. of the 6th.

The second typhoon was shown by our weather maps as formed on the 5th to 6th to the east of southern Luzon, in about 14° or 15° latitude N. and 132° or 133° longitude E. It moved NNW. until the 11th, when, after crossing the Loochoos, it inclined westward. Following are the positions of the center at 6 a. m. of the 10th, 11th, and 12th:

August 10, 6 a. m., 127° 50′ longitude E., 24° 00′ latitude N.
August 11, 6 a. m., 125° 50′ longitude E., 26° 45′ latitude N.
August 12, 6 a. m., 122° 45′ longitude E., 27° 35′ latitude N.

The third typhoon appeared near the Loochoos on the 29th, although it can be traced with some probability from the neighborhood of the Ladrone Islands beginning August 25.

The center was situated at 6 a. m. of the 29th, 30th, and 31st as follows:

August 29, 6 a. m., 128° 20′ longitude E., 25° 40′ latitude N.
August 30, 6 a. m., 125° 45′ longitude E., 27° 05′ latitude N.
August 31, 6 a. m., 123° 05′ longitude E., 28° 25′ latitude N.

Accordingly, the typhoon was moving to NW. by W. while traversing the Eastern Sea. On August 31 it inclined somewhat to the north and passed near to the south of Shanghai during the night of August 31 to September 1, moving NW. or NNW.

About the other three less important typhoons or depressions of the Eastern Sea we will only say that one of them formed on the 16th about 300 miles east of northern Luzon and moved N. until in the neighborhood of the Loochoos when it inclined westward on the 18th. The other two were formed just N. of Formosa on the 22d and 26th, respectively, and moved slowly ENE. until they disappeared after two or three days. The first filled up east of the northern part of the Loochoos, and the second in the Eastern Sea itself before reaching the Loochoos.

Japan typhoon.—Our weather map showed this typhoon on the 19th to the E. of the northern Ladrone Islands, in about 154° longitude E. and 18° latitude N. It moved NW. reaching the Bonins on the 22d, the barometer having fallen there to 724 mm. (28.50 ins.). On the 23d the typhoon recurved northeastward, the center passing near and to the south of Tokio at about noon of the 24th; then it moved NNE. near the eastern coast of Japan in the afternoon of the 24th and on the 25th.

Two depressions or typhoons over or near the Ladrone Islands.—The first of these depressions or typhoons was noticed south of Guam on the 5th, and probably recurved northeastward on the 6th to the W. of the Ladrone Islands. The second appeared on the 11th to 12th N. of Guam, over the central part of the Ladrone Islands, and moved probably N. and NE. on the 13th and 14th. Lack of observations makes it impossible to give these tracks as certain or to decide whether they were typhoons of any great importance.

FIVE TYPHOONS IN THE FAR EAST IN JULY, 1922.

By Rev. JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I., August 5, 1922.]

The first typhoon of the month was formed on the 3d to the east of northern Luzon near 126° longitude E. and 18° latitude N. It moved north and north by east, its center passing near Naha in the early morning of the 6th, when the barometric minimum, 732.7 mm. (28.85 inches), corrected for gravity, was observed. The typhoon crossed the Korea Strait and entered the Sea of Japan on the 8th.

The second typhoon was rather small and appeared for the first time near Surigao in about 10° latitude N. between 126° and 127° longitude E. at 6 a. m. of the 9th. It crossed the central part of the Philippines with a northwesterly direction, passed some 60 or 70 miles south of Manila in the afternoon of the 10th, traversed the China Sea practically with the same direction from the 10th to the 12th, and entered China about 150 miles west of Hongkong in the early morning of the 13th. The approximate position of the center on these days was:

July 11—132° 25′ longitude E. 16° 10′ latitude N.
July 12—113° 20′ longitude E. 20° latitude N.
July 13—111° 20′ longitude E. 22° 15′ latitude N.

On the 23d, after several days of a low-pressure area extending from the China Sea to the Pacific across northern Luzon and the Balintang Channel, a typhoon was formed in the eastern part of this region in about 19° latitude N. and 127° longitude E. It followed a track similar to the first typhoon of the month. The center was situated at noon of the 24th in about 28° latitude N. and 129° longitude E. At Oshima, or Nase, the barometric minimum was 726 mm. (28.58 inches) corrected for gravity. The direction of the typhoon was N. by E. until it reached Oshima, then NNW. until it reached the southwestern end of Korea, and NNE. again across Korea. The position of the center at noon of the 25th was about 34° latitude N. and between 126° and 127° longitude E.

A fourth typhoon was formed in the China Sea on the 26th between 16° and 17° latitude N. and in about 115° longitude E. It moved northwestward and entered the China coast north of Hainan in the early morning of the 29th.

The last typhoon of the month, and the most important for the Philippines, appeared on the 29th over 300 miles to the east of central Luzon in the Pacific. But as it traversed the Philippines on the 1st of August it rather belongs to the next month and therefore we will describe its track later, together with the other typhoons of August.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

Polar regions.—NOME, August 4.—The schooner *Maud*, carrying the Amundsen polar expedition, reported her position at midnight, August 2, as close to Wrangel Island and in ice, with fine weather prevailing and little snow. There had been several bad storms.—*Washington Post, August 4, 1922.*

British Isles.—The general rainfall expressed as a percentage of the average was: England and Wales, 132; Scotland, 78; Ireland, 104; British Isles, 109.

In London, Camden Square, the mean temperature was 59.1° F., or 3.3° F. below the average, the duration of rainfall 38.4 hours, and the evaporation 1.74 inch.[1]

Norway.—Arctic Norway reports summer heat such as has never before been known in that section. * * * At Hammerfest (just under 71 degrees north), the thermometer recorded a record temperature of 31 degrees Celsius (88 Fahrenheit), and at Tromso (just under 70 degrees north), 45 degrees Celsius (113 Fahrenheit) in the shade. * * *

In Bergen, just above 60 degrees north, the summer has been anything but warm. * * *.—*Excerpt from U. S. Consular Report, August 5, 1922.*

France.—At the middle of the month, southern France experienced a spell of hot weather, and a shade temperature of 98.6°F. was registered at Toulon. Many forest fires broke out, thousands of acres of woodland being involved.[1]

Switzerland.—On the 2d, hailstorms were experienced over wide areas of Switzerland, much damage being caused in the Cantons of Vaud, Berne, and Appenzell.[1]

Italy.—ROME, August 31.—After a drought which began May 10, Rome to-day was flooded by a terrific rainstorm and the temperature fell 20°F.—*New York Herald, September 1, 1922.*

India.—A pronounced break occurred in the Indian monsoon and the first half of the month was almost rainless in central and northwest India and the northern Deccan. Certain regions, however, had normal and even excessive rainfall, the latter occurring mainly on the Madras coast and in Bengal and Burma.[1]

China.—HONGKONG, August 7.—Estimates of the casualties in the typhoon, which last week (August 2) destroyed Swatow, now vary from 20,000 to 40,000. [Later reports give the number as greater than 50,000.] * * * Many villages were completely wiped out. * * * To-day gangs of Chinese fishermen were bringing, from 2 miles inland, their boats which had been blown into the country.—*Philadelphia Public Ledger, August 8, 1922.*

Korea.—TOKIO, August 24.—According to advices reaching here today, Korea is being swept by great floods. The dead are estimated to number a thousand.

So far no estimate has been made of damage, but it will be immense.—*Chicago Evening American, August 24, 1922.*

Chile.—On the 4th it was reported that heavy rains had caused extensive floods in Southern Chile with great damage to property and agriculture.[1]

Jamaica.—Kingston, August 29.—Hurricanes moving in the vicinity of Jamaica have had the effect of breaking the intense drought which was causing crops to perish in nearly all parts of the island.—*New York Times, August 30, 1922.*

Brazil.— * * * The rainfalls of the northern and southern regions were, respectively, 104 mm. and 46 mm. above normal while that of the center was 34 mm. below normal. Rio Minas and São Paula States had a long rainless spell.[1]

[1] *Meteorological Magazine*, September, 1922.

[1] *Meteorological Magazine*, September, 1922.

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

A. J. HENRY.

No feature of August weather stands out as exceptional; the three elements, pressure, temperature, and precipitation were in fairly close accord with normal conditions, excepting only the last named. The distribution of precipitation was quite irregular and local; on the whole it was a dry month, although more or less extensive areas of positive departure may be found in all parts of the country. On the Pacific coast and over the Plateau region, where August precipitation is normally small in amount, the departures were very generally positive. The drought was most severe in the Plains States and Texas.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

As usual, at this time of the year, the majority of the anticyclones were traced back to the North Pacific. The southern portions of these high-pressure waves are generally broken up and retarded on passing into the low-pressure belt over the Rocky Mountain region, while the northern portions are carried along more rapidly in the general circulation and lose less strength, appearing farther east as Alberta or Hudson Bay anticyclones at the time the southern portion of the original wave is disintegrating over the eastern slope of the Rockies. These pseudo Alberta and Hudson Bay anticyclones resemble the original from the North Pacific. The true Alberta anticyclone with its underrunning wedge of cold air should not be expected until there is a real accumulation of cold over the polar regions with the waning of summer.

Low-pressure areas were numerous but not important. No tropical cyclones were noted in this area of the western Atlantic.

CYCLONES.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
August, 1922	7.0	.....	.....	1.0	.....	.....	1.0	1.0	4.0	14.0
Average number 1892-1912, inclusive	4.2	0.6	0.3	0.9	1.0	0.2	0.1	0.1	1.0	8.4

ANTICYCLONES.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
August, 1922	4.0	.....	2.0	.....	2.0	8.0
Average number 1892-1912, inclusive	1.8	0.2	3.0	0.9	0.8	6.7

FREE-AIR CONDITIONS.

By L. T. SAMUELS, Meteorologist.

Mean temperatures were above the average at the four western kite stations at practically all levels (Table 1). Negative departures found at the surface and lower levels at Broken Arrow and Drexel, while not in agreement with surface-temperature departures as shown in climatological Chart III, may be explained as being a result of those kite flights made during the early morning hours and those in the later evening on a large portion of the days, at which times, only, favorable wind conditions existed. Negative departures were found at all levels at Royal Center and Due West. It will be noted that at Drexel and Ellendale, where temperature departures were positive (and moderately large at the latter station) the resultant winds for the month had a smaller southerly component than normally, a condition not often found. (See Table 2.) The percentage of sunshine for the month at these stations, however, was 77 per cent and 85 per cent, respectively, both amounts considerably exceeding any previous August for which records have been obtained. During the hot period in the south-central portion of the country in the latter part of the month when surface temperatures as high as 41° C were reported (on the 24th) at various points in this section, free-air temperatures at Broken Arrow exceeded all previous records at that station from the 1,000 to the 3,000 meter levels.

Relative humidities did not differ greatly from their average values excepting in the upper levels at Drexel, where they were over 20 per cent higher.

Vapor pressure departures conformed generally with those for temperature.

A calm period prevailed at Royal Center from the 9th to the 19th, inclusive, when winds remained too light to sustain kites. During the month only four single-theodolite pilot-balloon observations showed winds exceeding 30 m. p. s. These were as follows:

Station.	Date.	Velocity.	Direction	Altitude.
		M. p. s.		*Meters.*
Ellendale, N. Dak.	23	30	w.	8,200
Do.	24	33	w.	2,800
Ithaca, N. Y.	26	36	wsw.	5,700
Madison, Wis.	10	36	n.	8,200

Easterly winds above 10 km. were observed as follows:

Station.	Date.
Aberdeen, Md.	15
Bolling Field, D. C.	17, 18
Broken Arrow, Okla.	31
Camp Bragg, N. C.	22
Drexel, Nebr.	16
Groesbeck, Tex.	2, 5, 6, 7, 28, 31
Key West, Fla.	5, 24, 25, 31
Royal Center, Ind.	14, 17
Washington, D. C.	15, 16, 17, 18

A record pilot-balloon observation was made at Washington, D. C., on the 17th when an altitude of 22,590 m. was reached. At Broken Arrow on the 31st the balloon was observed to a height of 18,090 m. Both of these observations were made with a single theodolite and must therefore be accepted with reservation, at least for the upper levels. The record for Washington showed very light winds to 10 km. increasing from this elevation to a maximum of 19 m. p. s. at 12 km., above which they averaged between 8 and 14 m. p. s. The direction was westerly at the surface and backed to northeasterly at 10 km. where it remained to the highest altitude. At Broken Arrow the velocities averaged less than 10 m. p. s. throughout the observation. The direction was southwesterly at the surface, veering to northwesterly at 3 km. where it remained up to 14 km., then veered sharply until calm conditions were found at the highest levels.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during August, 1922.*

TEMPERATURE (°C.).

Altitude. M. S. L. (m.)	Broken Arrow, Okla. (233m.)		Drexel, Nebr. (396m.)		Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)		Groesbeck, Tex. (141m.)		Royal Center, Ind. (225m.)	
	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.
Surface	25.3	−1.3	22.6	−0.1	24.5	−0.3	23.1	+2.0	27.9	+1.3	22.5	−1.4
250	25.3	−1.2	.....	.....	24.2	−0.2	.....	.....	27.1	+1.4	22.3	−1.4
500	24.8	−0.1	22.0	−0.3	21.8	−0.1	23.0	+2.1	25.8	+1.8	20.0	−1.5
750	23.9	+0.3	21.8	+0.4	20.0	−0.1	22.1	+2.1	24.5	+1.6	18.4	−1.4
1,000	22.7	+0.3	21.1	+0.7	18.5	−0.3	20.8	+2.0	23.1	+1.3	17.0	−1.3
1,250	21.2	+0.3	20.1	+0.9	17.1	−0.3	19.5	+2.1	21.5	+1.0	15.5	−1.3
1,500	19.8	+0.5	18.5	+0.7	15.6	−0.3	18.2	+2.3	19.9	+0.9	14.1	−1.2
2,000	16.6	+0.8	15.4	+0.7	12.5	−0.5	15.3	+2.4	16.5	+0.	11.0	−1.4
2,500	13.4	+0.8	12.5	+1.1	9.6	−0.2	12.7	+2.7	13.2	+0.2	8.4	−1.5
3,000	10.6	+1.0	9.4	+1.5	6.5	−0.4	10.5	+3.3	10.0	−0.2	5.3	−2.0
3,500	7.5	+0.9	5.6	+1.0	2.7	−1.3	8.1	+3.7	10.0	+2.0	2.7	−2.0
4,000	.....	.....	1.9	+0.7	−1.3	−1.9	6.0	+4.6	9.1	+3.5	0.2	−2.0
4,500	.....	.....	−2.1	+0.3	−4.6	−2.4	4.4	+6.2	5.6	+3.5	.....	.....
5,000	.....	.....	−6.4	−0.2	.....	.....	2.4	+7.0	.....	.....	.....	.....

RELATIVE HUMIDITY (%).

Surface	71	+3	74	+5	70	−1	58	−5	66	−9	62	−3
250	70	+2	.....	.....	71	−1	.....	.....	66	−10	62	−3
500	62	−4	71	+5	75	0	57	−5	63	−13	65	0
750	58	−6	62	+1	77	0	54	−4	60	−10	65	−1
1,000	58	−5	58	−1	77	0	53	−4	60	−5	64	−2
1,250	58	−5	56	−2	77	−1	52	−5	62	−1	64	−3
1,500	55	−8	57	0	77	−1	52	−5	65	+2	65	−1

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during August, 1922*—Continued.

RELATIVE HUMIDITY (%)—Continued.

Altitude. M. S. L. (m.)	Broken Arrow, Okla. (233m.)		Drexel, Nebr. (396m.)		Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)		Groesbeck, Tex. (141m.)		Royal Center, Ind. (225m.)	
	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.
2,000	53	−11	58	+1	77	+2	52	−3	68	+5	67	+4
2,500	53	−9	57	0	73	−3	51	−1	70	+8	68	+10
3,000	49	−10	57	−1	71	−6	47	−3	71	+11	60	+9
3,500	50	−8	62	+5	69	−7	47	+1	63	+8	56	+9
4,000	.....	.....	66	+12	69	−3	45	−0	53	+10	55	+7
4,500	.....	.....	76	+22	63	−7	45	−1	53	+10	.....	.....
5,000	.....	.....	87	+28	.....	.....	.....	.....	.....	.....	.....	.....

VAPOR PRESSURE (*mb.*).

Surface	22.39	−0.84	19.82	+1.26	21.31	−0.65	15.76	+0.45	24.01	−1.76	16.63	−2.32
250	22.18	−0.87	.....	.....	21.03	−0.61	.....	.....	23.21	−1.64	16.52	−2.23
500	19.25	−1.30	18.34	+0.85	18.97	−0.34	15.63	+0.61	20.61	−1.69	15.17	−1.49
750	16.92	−1.37	15.78	+0.27	17.40	−0.38	14.20	+0.71	18.31	−1.08	13.77	−1.43
1,000	15.65	−1.05	14.19	+0.22	15.90	−0.49	12.93	+0.67	16.86	−0.10	12.31	−1.66
1,250	14.31	−0.93	13.00	+0.32	14.65	−0.49	11.83	+0.65	15.92	+0.66	11.38	−1.56
1,500	12.68	−1.12	11.95	+0.45	13.35	−0.36	10.87	+0.76	15.07	+1.00	10.45	−1.25
2,000	10.14	−1.22	9.94	+0.40	10.91	+0.01	9.08	+1.05	13.00	+1.37	8.87	−0.49
2,500	8.25	−0.61	8.00	+0.20	8.39	−0.62	7.57	+1.16	11.17	+1.52	7.56	+0.10
3,000	6.38	−0.50	6.54	+0.13	6.44	−0.89	6.15	+1.03	9.97	+1.93	5.21	−0.42
3,500	5.46	+0.08	5.54	+0.47	4.48	−1.37	5.21	+1.22	8.84	+2.41	4.13	−0.38
4,000	.....	.....	4.48	+0.65	3.20	−1.07	4.41	+1.24	7.69	+3.02	3.46	−0.35
4,500	.....	.....	3.72	+0.82	2.15	−1.34	4.22	+1.66	7.47	+3.02	.....	.....
5,000	.....	.....	2.83	+0.52	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 2.—*Free-air resultant winds (m. p. s.) during August, 1922.*

Altitude, m. s. l. (m.)	Broken Arrow, Okla. (233m.)				Drexel, Nebr. (396m.)				Due West, S. C. (217m.)				Ellendale, N. Dak. (444m.)				Groesbeck, Tex. (141m.)				Royal Center, Ind. (225m.)			
	Mean.		Average.		Mean.		Average.		Mean.		Average.		Mean.		Average.		Mean.		Average.		Mean.		Average.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 8° E.	2.7	S. 4° E.	3.5	S. 5° E.	1.9	S. 14° E.	1.6	N. 66° E.	1.5	N. 70° E.	1.0	S. 61° W.	0.6	S. 31° W.	1.0	S. 6° E.	1.9	S. 17° W.	3.0	S. 77° W.	1.2	S. 61° W.	1.7
250	S. 8° E.	2.8	S. 5° E.	3.6	.....	.....	.....	.....	N. 66° E.	1.5	N. 70° E.	0.9	.....	.....	.....	.....	S. 4° W.	2.6	S. 18° W.	4.1	S. 77° W.	1.4	S. 62° W.	1.8
500	S. 6° E.	4.6	S. 5° W.	5.0	S. 10° W.	3.0	S. 7° E.	2.3	N. 46° E.	1.4	N. 42° E.	0.8	S. 48° W.	0.7	S. 28° W.	1.6	S. 19° W.	3.6	S. 25° W.	6.0	S. 89° W.	3.6	S. 63° W.	3.6
750	S. 5° E.	5.4	S. 12° W.	5.7	S. 33° W.	4.0	S. 7° W.	3.3	N. 21° E.	1.3	N. 23° E.	0.8	S. 51° W.	2.1	S. 30° W.	2.5	S. 12° W.	3.2	S. 23° W.	6.0	N. 85° W.	4.9	S. 68° W.	4.4
1,000	S. 7° W.	4.9	S. 23° W.	6.1	S. 48° W.	4.4	S. 24° W.	3.5	N. 38° E.	1.0	N. 29° E.	0.7	S. 55° W.	2.7	S. 39° W.	2.8	S. 10° W.	2.9	S. 24° W.	5.9	N. 80° W.	5.2	S. 74° W.	5.2
1,250	S. 17° W.	4.3	S. 32° W.	5.9	S. 62° W.	4.0	S. 37° W.	3.8	N. 28° E.	1.1	N. 19° W.	0.5	S. 59° W.	3.1	S. 48° W.	3.1	S. 3° W.	2.3	S. 23° W.	5.7	N. 72° W.	6.8	S. 80° W.	5.9
1,500	S. 30° W.	3.7	S. 38° W.	5.6	S. 79° W.	3.7	S. 50° W.	3.9	N. 34° W.	0.8	N. 72° W.	1.4	S. 69° W.	3.6	S. 59° W.	3.4	S. 7° E.	1.7	S. 21° W.	4.9	N. 74° W.	7.5	S. 84° W.	6.6
2,000	S. 44° W.	2.1	S. 45° W.	5.2	N. 86° W.	4.5	S. 66° W.	5.1	N. 37° W.	7.5	N. 68° W.	1.8	S. 81° W.	5.1	S. 76° W.	4.3	S. 37° E.	1.0	S. 17° W.	4.2	N. 77° W.	8.8	S. 83° W.	7.7
2,500	S. 40° W.	1.7	S. 53° W.	5.4	N. 83° W.	5.7	S. 74° W.	6.5	N. 41° W.	2.1	N. 68° W.	3.0	S. 86° W.	7.1	S. 88° W.	9.2	S. 64° E.	1.7	S. 22° W.	4.3	N. 86° W.	10.6	S. 89° W.	8.9
3,000	S. 68° W.	1.3	S. 56° W.	6.8	N. 69° W.	8.6	S. 81° W.	8.3	N. 51° W.	3.3	N. 83° W.	4.7	N. 87° W.	8.5	N. 86° W.	7.4	N. 22° E.	7.7	S. 22° W.	4.5	N. 83° W.	14.3	N. 87° W.	10.4
3,500	N. 66° W.	2.4	S. 48° W.	7.7	N. 68° W.	8.0	S. 81° W.	9.3	N. 56° W.	5.4	N. 88° W.	6.6	N. 77° W.	10.0	N. 81° W.	9.9	.....	.....	.....	.....	N. 66° W.	6.7	N. 89° W.	10.2
4,000	.....	.....	.....	.....	N. 63° W.	11.0	S. 84° W.	10.5	N. 69° W.	10.5	N. 81° W.	7.5	N. 68° W.	9.4	N. 78° W.	10.2	.....	.....	.....	.....	N. 86° W.	10.0	S. 88° W.	11.7
4,500	.....	.....	.....	.....	N. 51° W.	15.7	N. 73° W.	10.2	N. 72° W.	10.5	N. 80° W.	13.0	N. 45° W.	12.9	N. 81° W.	10.2	.....	.....	.....	.....	.....	.....	.....	.....
5,000	.....	.....	.....	.....	N. 45° W.	14.0	N. 81° W.	14.1	.....	.....	.....	.....	N. 45° W.	14.7	N. 88° W.	12.5	.....	.....	.....	.....	.....	.....	.....	.....

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist in Charge of Division.

PRESSURE AND WINDS.

During August the first sign of approaching autumn is noted in the increased strength of the anticyclonic areas that occasionally move from the Canadian Provinces into the northern districts of the United States, particularly to eastward of the Rocky Mountains, as compared with those entering the United States during July. As a result the average atmospheric pressure for August is slightly higher as a rule than that for July over the northern half of the country from the Rocky Mountains eastward. On the other hand, in the southern districts, from Texas eastward, the increasing tendency during August of tropical hurricanes to visit this region, as compared with July, with their attendant low barometric pressure, causes a slight average decrease in pressure from the July values in that region. On the Pacific coast the continued warmth over the land areas, and the further heating of the adjacent ocean cause, on the average, a considerable lowering of the pressure of August from the July values.

During August, 1922, the average pressure was lower than that for the preceding month in nearly all districts, but particularly so over the Gulf States and in the far Northwest.

Compared with the normal the average pressure was higher over most central and southern districts, and also from the Great Lakes eastward, the greatest excesses appearing from the middle Rocky Mountains westward. From the middle Mississippi Valley northwestward into the Canadian Provinces the average pressure was slightly less than normal, and there were small areas along the Atlantic and Gulf coasts with averages likewise less than normal.

The relative position of the high and low pressure areas was in accordance with the condition usually existing during the warmer period of the year, and the resultant

winds were likewise of the normal types, southerly over the Great Plains and Atlantic coast districts, and mainly variable in other portions of the country.

As is usual during the summer months, high winds were mainly of a local character and usually associated with thunderstorms, although on the 24th and 25th high winds occurred over an extensive area from the Dakotas to the Great Lakes, due to the passage eastward of a disturbance of considerable energy near the Canadian boundary.

No important cyclones moved over extensive tracks and such as occurred had mainly little effect upon the general circulation. A list of the more important storms of the month follows at the end of this section.

TEMPERATURE.

The month as a whole was distinctly warm over the great central valleys, and mainly cool over eastern districts, but without marked variations from normal conditions save in a few instances at any period.

The first week had temperatures moderately above normal over much of the country, the main exceptions being a considerable area from the Great Lakes and Ohio Valley northeastward to New England, and the Central Plateau region, where the week was mostly cool.

The second week was very generally cool from the Great Plains eastward, and over most of the Plateau and Pacific Coast States. This week, however, was distinctly warm over the Dakotas and portions of adjacent States, where the averages ranged from 6° to 9° per day above normal, and it was generally warmer than normal over the entire Rocky Mountain region.

The period from the 15th to 22d had generally high temperatures throughout all interior portions of the country, the maximum temperatures rising frequently above 100°, and the average for the period ranging from 6° to 9° above normal over the Great Plains and portions of adjacent regions. On the Pacific coast, and over the Southeastern States this period continued cooler than normal.

The last week of the month was warm in all portions of the country, save from the Ohio Valley and middle Gulf States eastward. In the Great Plains maximum temperatures were again frequently above 100°, particularly in Kansas, Oklahoma, and portions of adjoining States, and the average for the week again ranged from 6° to 9° above the normal over extensive areas between the Mississippi Valley and the Rocky Mountains, and also over portions of the far Northwest. In the more eastern districts the weather remained cool as had been the case for several previous weeks.

Although no records of highest or lowest temperatures for long periods were exceeded during the month, yet on the whole it was the warmest August in many years over the Great Plains and northern Rocky Mountain regions, due in the southern districts to high day temperatures, and in the northern to unusually warm nights. On the other hand, over the southeastern sections, particularly near the coast, it was among the coolest and in some cases the coolest August in the past 50 years or more. This was brought about largely by an unusual number of cloudy, rainy days.

The warmest periods of the month were on the 1st and 2d over the greater part of the Gulf and South Atlantic States, and in the far Northwest; about the 16th to 18th over the Ohio Valley, Great Lakes, and to the eastward; from the 20th to 24th over the Mississippi Valley and Great Plains, where maximum temperatures were mostly well above 100°, rising to an extreme of 118° on the 24th at Oakwood, Okla., the highest ever recorded in that State; in the western Mountain regions the highest temperatures occurred mainly during the last week of the month.

The lowest temperatures of the month occurred on widely scattered dates, but mostly during the last decade. East of the Rocky Mountains the lowest temperatures did not reach the freezing point save in a few instances along the northern border, the lowest recorded, 28° on the 29th, being reported from Meadowlands in northern Minnesota, where slight frost damage occurred. The lowest temperature reported in the whole country, 21°, occurred in the mountains of Wyoming, and a close second, 22°, was reported from a mountain station in Oregon.

PRECIPITATION.

The notable feature of the precipitation during the month was the almost universal deficiency, as compared with the amounts usually received, over the great central valleys and eastern districts. The deficiencies were large over many of the great corn-growing areas, particularly in the States to westward of the Mississippi, and large deficiencies occurred in the East Gulf States also. In the Rocky Mountain States and thence westward to the Pacific precipitation was mainly above the average, particularly in the far Northwest, where a drought of the longest known duration at points in Washington was broken early in the month.

In portions of the middle and southern Plains region the precipitation was wholly insufficient for growing vegetation, and at Oklahoma City it was the least ever observed in August. In portions of eastern New Mexico the drought that had persisted through June and July continued during August, and the summer as a whole was the driest ever known.

Most of the precipitation was the result of thunderstorm activity, and the daily and monthly amounts showed the usual large variation within short distances. In some of the driest sections local areas had sufficient rain, notably in portions of the upper Ohio Valley near Parkersburg, where the heaviest precipitation of record for periods of one and two days occurred.

Precipitation was well distributed during the month, though the amounts were mainly less than normal, over the Atlantic coast districts, particularly from North Carolina to Florida, and rain was frequent in Colorado and adjoining portions of the mountain and Plateau regions.

RELATIVE HUMIDITY.

As may be usually expected, the departures of the relative humidity from normal values roughly outlined the areas of excessive and deficient precipitation. Thus in the great central valleys there was mainly deficient relative humidity, the negative departures ranging up to 15 per cent or more.

From the Rocky Mountains westward, the relative humidity was, on the whole, above normal, the positive departures ranging up to nearly 20 per cent. In this region, however, there were well-marked exceptions, notably in the Great Valley of California, where locally there were large negative departures. Over the Atlantic coast districts the relative humidity was mostly above normal.

SEVERE LOCAL STORMS.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the chief of bureau.]

Place.	Date.	Time.	Width of path. (yards).	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Carroll, De Kalb and Marion Counties, Ill.	1					Hail	Crops injured. In Marion County crop loss severe and windows broken.	Official, U. S. Weather Bureau.
Pueblo County, Colo. (SE. portion of).	1					Rain	Damage by flooding to growing crops and haystacks.	Pueblo Chieftain (Colo.).
Crawford and Dane Counties, Wis.	1	2:00 - 4:30 p. m.			$500,000	Hail	Two hailstorms leveled crops and caused other heavy damage.	Telegraph-Herald (Dubuque, Iowa); Official, U. S. Weather Bureau.
Stoughton, Wis. (4 miles W. of).	1					Thunderstorm	School building struck by lightning and burned. Damage by hail and lightning to tobacco crop feared.	Capital Times (Madison, Wis.).
Toledo, Ohio	2					Thunderstorms	Streets flooded and high tension wires struck, causing some damage. Several fires caused by lightning.	Blade (Toledo, Ohio); Official, U. S. Weather Bureau.
Nashville, Tenn	2					Wind and hail	Considerable damage to trees and crops	Do.
Detroit, Mich	2					Thunderstorm	Telephone and street car service crippled	Free Press (Detroit, Mich.); Official, U. S. Weather Bureau.
Hot Springs, S. Dak	2				1,000,000	Cloudburst	Heavy property damage. City isolated for several hours from the rest of the State.	Evening Star (D. C.).
Ware Cross Roads, S. C., and adjacent territory.	3	8:30 - 9:30 p. m.			50,000-100,000	Hail	One of a series of storms in that part of the State. Cotton completely destroyed, corn severely damaged, and other crops hurt; poultry and birds killed.	Official, U. S. Weather Bureau; Greenville News (S. C.).
Lansing, Mich	3	P. m.				Rain and hail	Streets and basements flooded. Other minor damage.	State Journal (Lansing, Mich.); Capital News (Lansing, Mich.).
Dinwiddie County, Va. (NW. part of).	3			1		Thunderstorm	Tobacco and other crops destroyed and several head of cattle killed.	Washington Post (D. C.).
Cabarrus, Rowan, Wilkes, Alexander, Catawba, and Iredell Counties, N. C.	3-4					Hail	Cotton, corn, and other crops severely damaged	Official, U. S. Weather Bureau.
Anne Arundel County, Md. (southern part of).	4		1,760		2,000	do	218 acres of tobacco and 346 acres of corn damaged.	Do.
Talbot County, Md. (northern portion of).	4				100,000-200,000	do	Heavy loss in fruit	Do.
Dedman, N. Mex	4	2 p. m.			5,000	Wind, rain, and hail.	Trees uprooted, fences torn down, one home destroyed, crops damaged, and some loss of stock. Other property damage and several persons injured.	Do.
Avondale, Colo., and vicinity.	4					do	Crops ruined by hail and water. Communication cut off.	Pueblo Chieftain (Colo.).
Farmington, Conn., and vicinity.	4			1		Electrical and rain	Crops destroyed, public utilities tied up, barns burned, and buildings damaged.	New York Herald.
Johnstown, N. Y	6	P. m.				Wind, rain, and hail.	Public utilities crippled, trees and small structures damaged. Poles down.	Morning Sun (Binghamton, N. Y.).
Cleveland, Ohio, and vicinity.	7	P. m.				Wind	Trees uprooted, wires snapped, traffic congested, and many lives endangered.	Commercial Appeal (Cleveland, Ohio).
Abilene, Tex. (near)	7	P. m.			2,000	do	5 persons injured. Crops and buildings damaged.	Official, U. S. Weather Bureau.
Albemarle County, Va	7	3 p. m.	880			Tornado [1]	Trees, crops, and barns damaged. Camp of the Lewis clan destroyed.[1]	Official, U. S. Weather Bureau; Evening Leader (Staunton, Va.).
New York City, N. Y., and vicinity.	7	P. m.		1		Hail and thunderstorm.	5 persons injured and minor property damage	Official, U. S. Weather Bureau; Tribune (N. Y.).
Morgan, Washington, Weld, and Adams Counties, Colo.	7-8				2,000,000	Hail and wind	Area covered about 680 square miles. Heavy damage to crops and loss of live stock; train of the C., B. & Q. R. R. damaged to the extent of $1,200 near Pinneo; several persons injured.	Official, U. S. Weather Bureau.
Boone County, Iowa	9	P. m.				Wind, rain, and hail.	Considerable damage done	Tribune (Chicago, Ill.).
Fisherville, Va	16	P. m.				Wind	Considerable damage to crops and buildings	Evening Star (D. C.).
Chattanooga, Tenn	17	P. m.				Electrical and wind.	Electric light and power lines damaged	Official, U. S. Weather Bureau, Chattanooga News (Tenn.).
Enid, Okla	18	P. m.				Wind and rain	Several persons injured; one house wrecked and several damaged. Streets flooded.	Herald (D. C.).
Central New York	18			1		Wind, rain, and electrical.	Property considerably damaged; traffic crippled and some live stock killed.	Standard (Cortland, N. Y.).
Abilene, Tex. (near)	19		150			Tornado	Minor damage	Official, U. S. Weather Bureau.
St. Louis, Mo	22	A. m.			600	Thunderstorm	Electric car and telephone service crippled temporarily. Fires caused by lightning.	Official, U. S. Weather Bureau. Globe-Democrat (St. Louis, Mo.).
Canisteo, N. Y	23					Electrical and rain	Barn and contents destroyed by lightning, and other minor damage.	News (Buffalo, N. Y.).
Central New York	23-25			2	1,500,000	Thunderstorms and wind.	Heavy property damage by lightning and floods. Live stock and crops destroyed and a number of people injured. Geneva hardest hit.	Standard (Cortland, N. Y.); Morning Sun (Binghamton, N. Y.).
Jamestown, N. Y	24	1-7 a. m.				Electrical	Damage to business houses and dwellings by lightning and floods.	News (Buffalo, N. Y.).
Gogebic County, Mich	24	P. m.				Wind, rain, and hail.	All electric power lines out of commission. Mines closed. Trees and roofs damaged.	Escanaba Daily Press (Mich.).
Chicago, Ill., and suburbs	24	P. m.		1		Wind and rain	Several persons injured; streets flooded and traffic delayed.	Official, U. S. Weather Bureau.
St. Paul, Minn., and vicinity.	24	P. m.				Wind	Power and telephone lines torn down; minor damage to buildings and several persons injured.	Pioneer Press (St. Paul, Minn.).
Louisville, Ky., and Jeffersonville, Ind.	25	A. m.	880	1	125,000	Wind and rain	Houses unroofed, trees and poles down, and other damage done. Numerous injuries.	Official, U. S. Weather Bureau; Indianapolis News (Ind.).
Port Huron, Mich., and vicinity.	25	A. m.				Thunderstorm	Local industries and street-car lines tied up. 3 barns burned and other property damage.	Official, U. S. Weather Bureau.
Richmond, Ind	25	A. m.				Wind and rain	Fruit, corn, and trees suffer. Other minor damage.	Indianapolis News (Ind.).
Valparaiso, Ind	25	A. m.				Thunderstorm	General damage done	Do.
South Bend, Ind	25	A. m.				do	Telephone system badly damaged and a barn and contents destroyed.	Do.
Anderson, Ind	25	A. m.			5,000	Electrical	Large barn burned and a horse killed	Do.
Corry, Pa., and west of	25	P. m.	35		10,000	Tornado	General damage done. 2 persons injured	Official, U. S. Weather Bureau.
Galatea, N. Y	25	P. m.				Cloudburst	Many bridges damaged	Standard (Cortland, N. Y.).
Norfolk, Va	27				50,000	Rain and wind	Roofs blown off and buildings otherwise damaged.	Official, U. S. Weather Bureau.
Baltimore, Md. (suburbs northeast of).	31				5,000-7,500	Hail	Glass in greenhouses broken within an area of 1 square mile.	Do.

[1] For a detailed description of this tornado see pp. 426-427 of this REVIEW.

STORMS AND WEATHER WARNINGS.

EDWARD H. BOWIE, Supervising Forecaster.

Disturbance over Caribbean Sea.—The morning observation of the 26th from Kingston, Jamaica, reported a heavy swell from the south, cirrus clouds from the southwest, intermediate low clouds from the southeast, stratus clouds from the east, wind north but changeable, and barometer 29.84 inches. Moreover the observations received from ships by radio indicated disturbed conditions over the southwest Caribbean Sea. Consequently advices were issued at 10 a. m. to the effect that there were indications of a disturbance some distance south-southwest of Jamaica and moving northwest. Later information substantiated the first warning issued. The disturbance of moderate intensity moved west-northwestward, apparently crossed the north portion of Honduras, the southern portion of the Gulf of Honduras, extreme southern British Honduras, and finally broke up in the mountain regions of Guatemala, although its influence extended far west of that Republic, as might be inferred from the reports of excessive rains in the southern States of Mexico and strong northerly winds from the vicinity of Vera Cruz, Mexico.

WASHINGTON FORECAST DISTRICT.

On the morning of the 7th when an area of low barometer was central over the region of the Great Lakes, southwest storm warnings were ordered raised on the Atlantic coast at and north of Delaware Breakwater. This disturbance moved eastward attended by squalls and strong winds and passed off the coast on the 8th. On the 18th small-craft warnings were displayed at and north of Atlantic City, to warn of the coming of thunderstorms and squalls of the afternoon and night of that day, while on the 25th southwest storm warnings were displayed along the Atlantic coast at and north of Delaware Breakwater. The morning of the 25th an area of low barometric pressure had its center north of the region of the Great Lakes, whence it moved down the St. Lawrence Valley. It was attended by fresh and strong shifting winds and thunderstorms along the coast where warnings were displayed. No warnings of unusual temperatures were issued during the month.

CHICAGO FORECAST DISTRICT.

The month was uneventful in the Chicago forecast district so far as special warnings were concerned, no general warnings of any character being issued.

Small-craft warnings were issued to most of the Lake stations on the 7th, and an advisory message in the afternoon of the 28th, to points on Lakes Michigan and Huron.

Fire-weather forecasts for western Montana were continued during the month to the district forester at Missoula, and they were begun to the State forester at St. Paul, Minn., August 19, for the timber regions in northeastern Minnesota.

The special forecasts which had been sent to Sturgeon Bay, Wis., since May 11, 1922, for the fruit interests, especially in connection with spraying, were discontinued on August 23, 1922.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT.

Moderate weather conditions prevailed in the west Gulf region during August, 1922. No storm warnings were issued and no storms occurred without warning.—*I. M. Cline.*

DENVER FORECAST DISTRICT.

The low pressures that are usual in midsummer prevailed in Arizona and on most of the Rocky Mountain plateau, only occasional areas of high pressure of feeble intensity crossing the Rocky Mountain region. These conditions were attended by frequent showers and thunderstorms, especially in the northern and eastern portions of the district. The temperature was generally above normal in all four States and was especially high in Colorado and New Mexico.

On the evening of the 18th, when a narrow trough of low pressure extended from British Columbia southward to Arizona, and at a time when the fire hazard was reported to be great in portions of Utah, the following fire-weather warning was issued: "Fresh to strong shifting winds and occasional thunderstorms indicated for Utah Saturday." Showers and thunderstorms occurred over the State on the following day, with fresh winds in southern Utah. During the remainder of the month showers were frequent and the amounts of precipitation sufficient to reduce materially the danger from fire. No other warnings were prepared.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT.

No striking abnormalities in pressure took place during August in the San Francisco forecast district. The barometer was relatively low over Alaska until the 24th, after which it was higher than usual. Showers occurred in the North Pacific States during 10–12th and on the last two days of the month. Rain fell locally on a few other occasions, but in no great amounts, except in Nevada, where a "cloudburst" flooded the residential section of the town of Ely and did damage estimated at $100,000. No lives were lost.

Fire-weather warnings were issued on the 17th for the entire district except in southern California. The expected hot weather with dry northerly winds occurred, but lasted only for a day and a half, when it was thought they would continue for about three days. Special daily forecasts were sent on the 7th to the supervisor of Wenatchee Forest, in Washington, to aid him in directing the movements of men employed in putting out a large forest fire. They were continued for four days, when he was notified that showers would occur. The showers came as predicted and the forecasts were then discontinued.

No other warnings were needed nor were any issued during the month.—*E. A. Beals.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

There were no floods during the month, and most rivers fell steadily, marking the beginning of the normal low-water season that usually reaches its culmination during October and early November.

The Santee River was above the flood stage for a few days, but as this river had been near or above flood stage since the preceding February, no crops had been planted in the lowlands, no cattle were grazing, and consequently there were no losses.

Flood stages during August, 1922.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Santee:	*Feet.*			*Feet.*	
Rimini, S. C.	12	12	14	13.1	13
Do	12	17	21	12.8	19
Ferguson, S. C.	12	(1)	1	12.0	1
Do	12	13	24	12.7	15

[1] Continued from July.

MEAN LAKE LEVELS DURING AUGUST, 1922.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., September 5, 1922.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during August, 1922:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.63	580.56	572.50	246.56
Above or below—				
Mean stage of July, 1922	+0.14	−0.11	−0.26	−0.36
Mean stage of August, 1921	−0.14	+0.38	+0.01	+0.63
Average stage for August, last 10 years	−0.09	−0.40	−0.28	−0.02
Highest recorded August stage	−1.30	−2.95	−1.61	−1.70
Lowest recorded August stage	+1.03	+0.71	+1.12	+2.21
Average relation of the August level to:				
July level		−0.10	−0.20	−0.30
September level		+0.20	+0.30	+0.40

[1] Lake St. Clair's level: In August, 575.33 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS: AUGUST, 1922.

By J. WARREN SMITH, Meteorologist.

The first half of August, 1922, was mostly cool for the season from the Mississippi Valley eastward, which somewhat retarded the ripening of summer crops, but the latter half was much warmer and crops matured rapidly. Rainfall was very unevenly distributed geographically, the amounts being scanty in much of the interior and the drought from Oklahoma southward and southwestward was intensified and had become severe at the close of the month. The lack of moisture that had prevailed in the far Northwestern States was largely relieved by copious rainfall near the middle of the month and beneficial rains were received in most sections from the Ohio Valley northward and northeastward during the latter part.

The month on the whole was generally favorable for harvesting small grains in the later districts and for threshing winter wheat, while late spring wheat was benefited early in the month by the showers that were received in the northern Rocky Mountain areas. Considerable rust was reported in spring wheat in eastern North Dakota, but it developed too late to cause widespread damage. Preparation of soil for the seeding of winter grain made rather slow progress in much of the interior of the country because of hard, dry soil, but conditions were improved in the lower Missouri and parts of the upper Mississippi Valleys, as well as in portions of the Great Plains area, by rainfall about the 20th.

The first half of the month was somewhat too cool for the best development of corn from the Lake region eastward and moisture was deficient during much of the month in some interior localities, particularly in parts of the Ohio Valley. The crop made good progress in most of the upper Mississippi Valley area and the late crop was favored in the Ohio Valley and eastern Missouri by the rains near the close of the month. The hot, dry weather was very unfavorable from Kansas southward, however, and late corn was severely damaged in that area. The crop matured rapidly during the last half of the month and at the close was mostly out of frost danger in the extreme northern Great Plains.

The weather was generally unfavorable for cotton in nearly all sections of the belt. The drought in the western cotton-growing States continued mostly unrelieved throughout the month and was accompanied during much of the time by extremely warm weather. Cotton made very good progress in limited areas where showers occurred, but on the whole general deterioration was reported in the western portion of the belt. There was less rainfall in the eastern portion than had been previously experienced, but it was rather too cool during much of the month, particularly during the latter part, with much cloudy weather. Picking and ginning advanced rapidly under favorable weather conditions and bolls opened fast, particularly in the western portion of the belt.

Grasses, truck, and miscellaneous crops were benefited by rainfall in the northeastern section of the country during the latter part of the month but it was too dry in most of the South, in much of the Great Plains area, and some other interior localities. Ranges were unfavorably affected by dry weather in the Southwest, except that conditions were fairly favorable in Arizona. At the close of the month stock were in very poor condition in most of New Mexico and only fair in much of western Texas.

CLIMATOLOGICAL TABLES.[1]

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, August, 1922.

Section.	Temperature.							Precipitation.					
			Monthly extremes.							Greatest monthly.		Least monthly.	
	Section average.	Departure from the normal.	Station.	Highest.	Date.	Station.	Lowest.	Date.	Section average.	Departure from the normal.	Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	78.9	−0.7	Madison	101	[2]1	3 stations	52	[2]11	3.27	−1.54	Silverhill	7.88	Leeds	1.07
Alaska														
Arizona	80.0	+1.4	Mohawk	118	31	Fort Valley	42	2	2.33	+0.04	Bisbee	7.40	Yuma Date Orchard	0.09
Arkansas	80.4	+1.0	Hope	111	23	Dutton	51	[2]27	1.90	−1.93	Marked Tree	8.43	Wynne	0.21
California	71.3	−1.2	Greenland Ranch	122	27	Portola	27	14	0.08	−0.02	Warner Springs	2.35	127 stations	0.00
Colorado	67.0	+2.8	Sedgwick	104	30	Crested Butte	25	9	2.13	+0.11	Fremont Experiment Sta.	7.39	Garnett	0.07
Florida	80.1	−1.3	3 stations	99	[2]2	DeFuniak Springs	59	4	8.24	+1.44	Bradentown	19.35	Bluff Springs	1.46
Georgia	77.9	−1.6	Hazlehurst	103	1	Clayton	45	28	3.47	−2.05	Savannah	8.18	Canton	0.86
Hawaii	74.8	0.0	Mahukona, Hawaii	94	28	Volcano Observatory	51	23	4.36	−2.05	Eke, Maui	17.50	8 stations	0.00
Idaho	68.1	+2.3	Kooskia	108	26	Stanley	23	16	1.55	+0.88	Hereford	3.55	Glenns Ferry	0.10
Illinois	75.1	+1.0	Alexander	104	24	2 stations	42	[2]9	1.70	−1.62	Nashville	2.21	Rockford	0.21
Indiana	73.7	+0.3	2 stations	103	17	2 stations	42	[2]10	2.11	−1.15	Greenfield	5.28	Williams	0.48
Iowa	73.8	+2.0	2 stations	102	[2]17	Mason City	42	8	3.06	−0.62	Atlantic	9.00	Le Claire	0.33
Kansas	80.1	+2.9	Beloit	113	24	4 stations	48	27	1.47	−1.70	Macksville	5.19	McFarland	0.00
Kentucky	75.2	−0.5	Earlington	101	18	Farmers	47	28	2.43	−1.13	Bowling Green	5.82	Cloverport	0.61
Louisiana	81.3	−0.2	2 stations	103	[2]20	Kelly (near)	55	28	5.26	+0.09	Donaldsonville	10.21	Ruston	0.74
Maryland-Delaware	71.8	−1.7	2 stations	98	18	2 stations	31	21	3.38	−1.06	Salisbury, Md	9.17	Baltimore, Md	1.11
Michigan	67.3	+1.0	Morenci	102	17	Humboldt	30	20	2.14	−0.74	Mio	5.18	Mackinac Island	0.56
Minnesota	70.3	+3.9	3 stations	105	16	Meadowlands	28	29	1.78	−1.59	New London	3.88	Lynd	0.42
Mississippi	80.1	−0.3	2 stations	101	[2]1	3 stations	54	11	3.19	−1.17	Aberdeen	9.43	University	0.10
Missouri	77.5	+1.2	Hollister	107	23	Louisiana	46	9	2.40	−1.60	Vanduser	6.22	Bolivar	0.13
Montana	67.8	+3.4	Glendive	104	12	3 stations	31	[2]14	1.36	+0.24	Hamilton	3.69	Crow Agency	0.00
Nebraska	76.5	+3.7	2 stations	109	24	Gordon	37	27	1.77	−1.00	Hayes Center	5.87	2 stations	0.12
Nevada	70.7	−0.5	Logandale	110	7	Rye Patch	25	20	1.14	+0.72	Searchlight	5.29	Minden	T.
New England	66.8	+0.1	Turners Falls, Mass.	96	16	2 stations	34	[2]9	5.32	+1.49	Plymouth, Mass.	11.63	2 stations	2.63
New Jersey	71.2	−0.9	3 stations	96	17	Charlotteburg	39	22	4.03	−0.65	Hammonton	6.78	Ridgefield	2.18
New Mexico	72.9	+2.5	Orogrande	110	[2]4	Senorito	36	26	1.54	−0.88	Cloverdale R. S.	9.93	3 stations	0.00
New York	66.9	−0.4	Port Jervis	96	17	Gabriels	32	9	4.77	+0.91	Geneva	9.14	West Point	1.20
North Carolina	73.5	−2.2	Smithfield	97	2	2 stations	39	[2]21	5.18	−0.32	Manteo	11.82	Asheville	1.64
North Dakota	69.8	+4.4	Cando	115	2	Lisbon	33	29	1.36	−0.92	Manfred	4.70	Bowman	0.14
Ohio	70.5	−1.3	Chilo	101	18	Millport	35	21	3.26	−0.33	Amesville	7.47	Green	0.79
Oklahoma	83.6	+3.0	Oakwood	118	24	Hooker	49	27	1.18	−1.79	Pauls Valley	5.66	3 stations	T.
Oregon	66.4	±0.0	2 stations	104	[2]1	La Pine	22	[2]14	0.97	+0.51	Classic Lake	6.68	2 stations	0.00
Pennsylvania	69.1	−1.2	Clearfield	100	17	West Bingham	31	[2]9	3.14	−1.03	Hamburg	8.16	Colebrook	1.15
South Carolina	76.4	−2.4	2 stations	98	[2]2	Walhalla	49	28	5.07	−0.98	Yemassee	12.73	Liberty	0.89
South Dakota	73.9	+4.0	Pollock	108	13	St. Francis	37	25	1.51	−1.14	Deerfield	4.46	Pollock	0.05
Tennessee	75.6	−0.9	Perryville	102	6	2 stations	46	[2]11	3.11	−1.08	Crossville	9.28	Henderson	0.37
Texas	84.4	+1.8	Quanah	114	[2]3	Clarendon	52	9	1.17	−1.43	Ringo Crossing	6.31	10 stations	0.00
Utah	71.2	+1.8	St. George	107	26	Ibapah	36	18	2.03	+1.04	Park City	7.45	Bluff	T.
Virginia	71.9	−1.6	West Point	95	7	Burkes Garden	37	29	4.44	−0.01	Diamond Springs	11.58	Lynchburg	1.18
Washington	66.1	+1.0	3 stations	104	1	Paradise Inn	32	31	1.49	+0.72	Silverton	5.29	2 stations	0.10
West Virginia	68.9	−2.8	3 stations	98	[2]17	Bayard	31	21	3.87	−0.07	Creston	7.51	Dam No. 13, Ohio River.	1.20
Wisconsin	68.6	+1.9	5 stations	97	[2]15	Long Lake	31	30	2.01	−1.38	Ripon	7.32	Kilbourn	0.35
Wyoming	67.3	+4.1	Basin	103	18	South Pass City	21	[2]22	1.50	+0.55	Bedford	3.75	Elk Mountain	0.16

[1] For description of tables and charts, see REVIEW, July, 1922, pp. 384-385.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1922.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.											Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. +mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.												
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F*		° *F.*	° *F.*		° *F*	° *F.*		° *F.*	° *F.*	%	*In.*	*In.*		*Miles.*													*0–10*	*In.*	*In.*
New England.							**67.4**	**+0.1**											**83**	**5.69**	**+1.8**														**6.1**		
Eastport	76	67	85	29.89	29.97	+.01	59.6	−1.1	87	16	67	48	3	52	36		56	54	89	9.44	+6.2	15	5,377	s.	29	sw.	7	4	11	16	7.2	0.0	0.0
Greenville, Me	1,070	6		28.83	29.98		63.2		84	15	74	41	22	53	33					3.41		13						15	6	10		0.0	0.0
Portland, Me	103	82	117	29.87	29.99	+.01	67.2	+0.8	94	16	74	53	22	61	26		61	58	78	2.75	−0.8	10	5,863	s.	32	se.	25	9	9	13	5.8	0.0	0.0
Concord	288	70	79	29.68	29.98	.00	67.7	+1.0	94	16	78	43	22	57	36					2.63	−1.1	12	2,918	s.	22	n.	21	13	5	13	5.4	0.0	0.0
Burlington	404	11	48	29.54	29.97	.00	66.2	+0.1	87	18	76	44	9	57	29					4.14	+0.1	13	6,123	s.	44	s.	25	10	7	14	6.1	0.0	0.0
Northfield	876	12	60	29.08	30.00	+.02	63.8	+0.9	88	16	76	37	9	52	36		59	58	87	4.18	+0.2	13	4,102	s.	28	sw.	18	6	10	15	6.5	0.0	0.0
Boston	125	115	188	29.85	29.98	−.01	70.4	+0.5	93	16	77	54	21	63	27		64	60	74	4.75	+0.7	13	5,983	sw.	26	sw.	7	11	6	14	5.9	0.0	0.0
Nantucket	12	14	90	29.97	29.98	−.01	68.2	+0.2	79	5	73	59	21	63	17		65	64	92	8.40	+5.4	13	11,490	sw.	37	s.	28	10	5	16	6.4	0.0	0.0
Block Island	26	11	46	29.96	29.99	.00	68.2	−0.5	82	17	73	55	21	63	15		65	63	89	9.53	+6.0	12	10,922	sw.	36	sw.	16	11	4	16	5.9	0.0	0.0
Providence	160	215	251	29.81	29.98	−.01	69.6	−1.4	91	16	78	52	21	62	26		64	61	77	6.96	+2.9	12	7,234	nw.	35	s.	25	8	10	13	6.2	0.0	0.0
Hartford	159	122	140	29.81	29.98	−.01	70.0	+1.1	91	16	79	52	22	61	28		64	62	82	6.84	+2.3	11	4,843	s.	27	sw.	25	8	9	14	6.4	0.0	0.0
New Haven	106	74	153	29.88	29.99	.00	70.3	0.0	91	16	78	54	21	62	26		64	61	78	3.01	−2.0	8	6,368	sw.	29	ne.	28	11	8	12	5.5	0.0	0.0
Middle Atlantic States.							**71.5**	**−1.5**											**78**	**4.16**	**−0.3**														**5.8**		
Albany	97	102	115	29.88	29.98	.00	69.8	+0.3	94	16	79	51	21	60	26		63	60	76	4.19	+0.2	16	4,623	s.	30	sw.	18	7	14	10	5.4	0.0	0.0
Binghamton	871	10	84	29.08	29.99	.00	67.4	−0.1	92	18	78	45	9	57	35					6.63	+3.3	16	2,889	e.	23	nw.	20	8	9	14	6.6	0.0	0.0
New York	314	414	454	29.66	29.99	−.01	71.4	−1.7	91	17	78	55	21	64	21		65	62	77	5.32	+0.8	16	9,909	sw.	43	nw.	16	8	7	16	6.6	0.0	0.0
Harrisburg	374	94	104	29.62	30.01	.00	71.4	−0.7	94	17	80	55	29	63	28		63	59	71	1.26	−3.0	8	3,643	w.	22	n.	16	7	15	9	5.6	0.0	0.0
Philadelphia	117	123	190	29.88	30.00	.00	73.0	−0.8	91	17	81	56	21	65	23		66	62	73	2.56	−2.0	12	6,645	sw.	32	s.	1	8	4	19	6.5	0.0	0.0
Reading	325	81	98	29.65	29.99		71.9		92	17	81	54	21	63	28		64	61	76	5.21	+0.7	14	2,791	sw.	17	sw.	16	9	9	13	5.8	0.0	0.0
Scranton	805	111	119	29.16	30.01	+.01	68.7	−0.6	94	17	79	49	21	58	34		62	58	74	2.56	−1.7	13	3,836	n.	34	sw.	26	7	11	13	6.3	0.0	0.0
Atlantic City	52	37	172	29.94	29.99	−.01	71.2	−1.3	85	5	76	53	21	66	21		68	66	85	5.13	+0.8	12	11,815	s.	50	se.	31	11	8	12	5.6	0.0	0.0
Cape May	18	13	49	30.01	30.03	+.03	72.7	−0.7	86	5	79	60	21	67	19		68	66	85	4.79	+0.5	12	5,997	sw.	27	se.	1	11	7	13	5.6	0.0	0.0
Sandy Hook	22	10	55	29.96	29.98		72.0		89	17	78	58	21	66	23		66	64	81	2.76		13	9,950	sw.	41	nw.	20	8	9	14	5.8	0.0	0.0
Trenton	190	159	183	29.79	29.99		71.0		90	17	80	54	21	63	26		65	62	77	5.16	−0.2	17	6,908	sw.	35	n.	20	7	8	16	6.7	0.0	0.0
Baltimore	123	100	113	29.86	29.99	−.02	74.1	−1.4	92	17	82	59	22	66	25		67	63	73	1.11	−3.1	13	3,989	sw.	20	ne.	31	10	12	9	5.4	0.0	0.0
Washington	112	62	85	29.88	30.00	−.01	73.1	−1.9	92	18	82	53	22	64	28		66	64	78	3.08	−1.3	12	3,612	sw.	24	s.	19	10	13	8	5.0	0.0	0.0
Lynchburg	681	153	188	29.28	30.01	−.01	72.8	−2.8	90	7	83	48	22	63	33		65	62	74	1.18	−3.1	10	4,274	w.	24	nw.	7	8	17	6	5.6	0.0	0.0
Norfolk	91	170	205	29.92	30.02	+.02	75.0	−1.7	90	5	82	60	22	68	23		69	67	81	8.04	+2.1	13	8,134	s.	38	nw.	27	5	13	13	6.3	0.0	0.0
Richmond	144	11	52	29.86	30.01	.00	73.3	−4.2	90	7	82	52	22	64	27		67	65	82	7.78	+3.4	14	4,803	s.	33	nw.	7	13	12	6	4.4	0.0	0.0
Wytheville	2,304	49	56	27.71	30.03	+.02	66.9	−3.6	83	6	76	46	21	57	31		61	59	83	2.52	−2.0	13	3,384	w.	44	e.	16	9	15	7	5.1	0.0	0.0
South Atlantic States.							**76.0**	**−2.2**											**81**	**5.24**	**−0.9**														**5.8**		
Asheville	2,255	70	84	27.74	30.04	+.02	69.0	−1.5	87	7	78	49	28	60	28		62	60	80	1.64	−3.2	8	4,326	nw.	28	e.	11	10	14	7	5.2	0.0	0.0
Charlotte	779	55	62	29.20	30.02	.00	74.9	−1.7	94	1	84	57	28	66	26		67	64	75	2.74	−2.8	12	2,983	ne.	24	nw.	2	8	8	15	6.0	0.0	0.0
Hatteras	11	12	11	30.00	30.01	+.01	75.8	−2.2	85	6	81	65	22	71	15		72	70	82	8.71	+2.9	13	7,203	sw.	50	nw.	3	12	9	10	5.3	0.0	0.0
Manteo	12	5	42				76.6		90	8	84	62	27	69	20					11.82		9		sw.				19	3	9		0.0	0.0
Raleigh	376	103	110	29.62	30.01	.00	74.4	−2.4	92	7	84	53	22	65	27		68	66	81	7.10	+1.2	13	4,757	sw.	34	w.	26	8	12	11	5.6	0.0	0.0
Wilmington	78	81	91	29.94	30.02	+.02	75.8	−1.8	90	1	83	62	22	68	22		71	69	84	5.42	−1.1	16	4,736	sw.	23	sw.	8	10	12	9	5.5	0.0	0.0
Charleston	48	11	92	29.96	30.01	.00	78.1	−2.9	95	1	84	66	28	72	20		73	72	84	5.18	−1.8	17	6,918	sw.	40	n.	2	7	9	15	6.1	0.0	0.0
Columbia, S. C	351	41	57	29.65	30.02	+.01	77.0	−2.5	95	1	86	59	23	68	27		69	67	78	1.76	−5.0	9	4,157	ne.	38	n.	2	8	13	10	5.6	0.0	0.0
Due West	711	10	55	29.28	30.04		75.9		94	1	85	57	28	67	29					2.24		11	4,947	ne.	39	n.	3	6	10	15	6.3	0.0	0.0
Greenville, S. C	1,039	113	122	28.93	30.00		74.7		93	1	83	58	28	66	27		67	63	74	0.95		11	5,253	ne.	28	ne.	9	9	10	12	5.8	0.0	0.0
Augusta	180	62	77	29.81	30.00	−.01	78.0	−2.4	98	1	87	61	29	69	27		71	69	80	3.97	−1.6	11	3,138	e.	23	sw.	2	7	10	14	6.5	0.0	0.0
Savannah	65	150	194	29.93	30.00	−.01	78.2	−1.2	96	1	86	66	28	71	25		72	70	85	8.18	+0.7	13	6,742	sw.	39	nw.	9	12	5	14	5.8	0.0	0.0
Jacksonville	43	209	245	29.95	30.00	−.01	78.8	−2.9	92	1	85	66	31	72	19		73	72	86	7.71	+1.5	16	7,773	s.	44	s.	4	5	16	10	6.0	0.0	0.0
Florida Peninsula.							**81.6**	**−0.7**											**76**	**6.67**	**−0.3**														**5.8**		
Key West	22	10	64	29.96	29.98	.00	83.2	−0.3	91	10	88	73	16	78	14		76	73	73	3.51	−1.2	8	5,511	se.	31	nw.	11	9	17	5	5.0	0.0	0.0
Miami	25	71	79	29.98	30.01		81.2	−0.8	89	21	87	69	30	76	19		75	72	76	7.97	+0.4	17	4,524	se.	33	nw.	3	3	17	11	6.2	0.0	0.0
Sand Key	23	39	72	29.97	30.00	+.02	81.9		89	21	85	71	13	79	13		76	73	73	1.76		11	6,934	se.	36	nw.	11	13	12	6	5.0	0.0	0.0
Tampa	35	79	92	29.96	29.99	−.01	80.4	−1.0	92	1	87	69	30	74	22		74	72	82	8.52	−0.1	19	4,420	s.	32	e.	13	1	19	11	7.0	0.0	0.0
East Gulf States.							**79.3**	**−0.3**											**78**	**3.96**	**−0.9**														**5.4**		
Atlanta	1,174	190	216	28.81	30.02	+.01	75.8	−1.2	94	2	84	61	28	67	28		68	66	77	2.72	−1.8	13	5,480	e.	36	nw.	25	11	6	14	5.9	0.0	0.0
Macon	370	78	87	29.61	30.00	−.01	78.2	0.0	96	1	87	62	30	69	25		70	68	76	2.52	−1.7	10	3,613	ne.	24	sw.	2	6	15	10	5.9	0.0	0.0
Thomasville	273	49	58	29.70	29.99	−.01	79.4	−1.6	94	4	88	64	23	71	24		72	70	81	2.71	−2.3	15	2,995	sw.	23	e.	20	3	8	20	7.5	0.0	0.0
Apalachicola	25	42	49	29.94	29.98		79.4		89	26	84	70	23	74	15		75	73	82	8.25		18	5,053	w.	27	se.	11	9	15	7	5.5	0.0	0.0
Pensacola	56	149	185	29.92	29.98	.00	79.7	−1.2	90	3	85	68	11	74	18		74	72	81	11.61	+4.4	14	7,611	w.	52	sw.	27	6	13	12	6.1	0.0	0.0
Anniston	741	9	57	29.25	30.03	+.04	76.4	0.0	95	1	87	54	28	65	30					1.40	−3.1	14	2,890	e.	20	n.	25	14	13	4	4.1	0.0	0.0
Birmingham	700	11	48	29.27	30.02	+.03	79.4	−0.4	98	1	90	60	28	69	27		79	65	72	2.95	−1.5	9	3,802	e.	31	w.	2	9	15	7	4.9	0.0	0.0
Mobile	57	125	161	29.92	29.98	.00	81.1	+0.6	94	3	89	68	11	74	23		74	72	81	5.13	−1.7	12	5,597	n.	39	nw.	3	5	19	7	5.5	0.0	0.0
Montgomery	223	100	112	29.75	30.00	+.01	80.3	+0.5	96	20	90	62	28	71	23		71	68	71	2.15	−2.1	8	4,237	e.	26	n.	26	13	11	7	4.7	0.0	0.0
Corinth	469	6					79.0		98	6	92	54	11	66	36					2.13		8		se.				9	21	1		0.0	0.0
Meridian	375	85	93	29.60	29.98	.00	79.2	+0.7	94	2	89	59	28	70	28		71	68	76	2.67	−0.9	7	3,131	ne.	20	n.	26	16	10	5	4.1	0.0	0.0
Vicksburg	247	65	73	29.73	30.00	+.02	79.8	−1.0	94	1	88	65	28	72	23		73	70	81	3.96	+0.4	8	3,828	n.	31	ne.	26	13	13	5	4.6	0.0	0.0
New Orleans	53	76	84	29.92	29.97	−.01	83.0	+0.8	95	20	90	71	1	76	20		75	73	78	5.71	+0.1	12	3,960	w.	28	ne.	17	7	14	10	5.8	0.0	0.0
West Gulf States.							**83.1**	**+2.0**											**70**	**1.23**	**−1.7**														**4.0**		
Shreveport	249	77	93	29.71	29.97	.00	82.1	+0.7	98	1	92	65	28	72	27		74	71	76	2.04	−0.2	10	3,630	ne.	29	se.	26	17	13	1	3.0	0.0	0.0
Bentonville	1,303	11	44				78.2	+1.7	102	24	90	54	9	66	36					0.78		6						22	4	5		0.0	0.0
Fort Smith	457	79	94	29.48	29.95	−.02	83.0	+3.6	103	22	94	62	26	72	27		71	67	64	1.88	−1.8	4	4,336	e.	35	nw.	26	12	14	5	4.3	0.0	0.0
Little Rock	357	136	144	29.61	29.97	−.01	81.5	+2.3	98	19	92	63	28	71	25		71	67	69	0.83	−2.8	5	4,693	e.	29	w.	7	15	11	5	3.7	0.0	0.0
Brownsville	57	4	26				84.8		98	9	94	70	13	75	23					2.43		8															0.0	0.0
Corpus Christi	20	11	73	29.94	29.96	+.03	83.6	+1.5	93	7	90	74	14	78	17		77	75	80	0.20	−2.1	3	8,198	se.	31	e.	14	10	17	4	4.3	0.0	0.0
Dallas	512	109	117	29.42	29.95		84.8		102	2	95	65	9	75	26					0.53		5	5,365	se.	24	ne.	26	13	14	4	4.5	0.0	0.0
Fort Worth	670	106	114	29.22	29.92	−.02	85.2	+2.3	103	1	96	67	9	74	27		70	64	57	0.52	−1.4	4	6,172	se.	27	s.	4	12	17	2	4.2	0.0	0.0
Galveston	54	106	114	29.92	29.98	+.02	83.1	+0.1	92	2	88	71	14	78	13		77	75	80	2.53	−2.5	6	5,893	se.	27	e.	30	11	17	3	4.4	0.0	0.0
Groesbeck	461	11	56	29.48	29.95		84.4		102	26	95	64	11	73	30					1.09		5	5,466	se.	59	n.	26	18	12	1	3.5	0.0	0.0
Houston	138	111	121	29.82	29.96		84.0	+1.1	98	3	93	69	14	75	27					1.72		6	4,425	s.	29	ne.	26	15	14	2	3.5	0.0	0.0
Palestine	510	64	72	29.44	29.96	−.01	82.8	+2.3	100	26	93	66	12	73	29		72	68	69	1.73	−0.5	8	3,976	e.	24	w.	26	12	14	5	4.5	0.0	0.0
Port Arthur	34	58	66	29.92	29.96		82.2		94	19	89	69	13	75	20		75	73	79	1.62		4	5,253	s.	30	ne.	3	8	20	3	4.7	0.0	0.0
San Antonio	701	119	132	29.23	29.93	.00	85.8	+3.8	100	3	97	69	12	75	26		71	65	59	0.27	−2.4	3	4,244	s.	28	se.	15	19	11	1	3.4	0.0	0.0
Taylor	582	55	63	29.38	29.99	+.04	84.7	+3.0	100	3	96	68	11	74	28					1.04	−1.4	5	4,934	s.	28	n.	26	14	14	3	4.2	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1922*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. +mean min.÷2	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.							Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*		*%*	*In.*	*In.*		*Miles.*									*0–10*	*In.*	*In.*
							74.0	**−0.7**											**70**	**3.25**	**−0.2**											**4.6**		
Chattanooga	762	189	213	29.22	30.02	+.02	75.4	−2.1	94	7	85	58	28	66	26	67	63	72	5.22	+1.5	13	4,422	nw.	44	se.	17	12	16	3	4.5	0.0	0.0
Knoxville	996	102	111	28.99	30.03	+.02	74.0	−0.7	91	6	84	55	28	64	27	66	63	74	3.47	−0.5	10	3,616	ne.	27	s.	7	8	13	10	5.8	0.0	0.0
Memphis	399	76	97	29.61	30.02	+.04	79.7	+0.3	93	6	88	63	27	72	21	70	66	68	0.76	−2.4	6	4,464	n.	27	sw.	25	16	8	7	4.2	0.0	0.0
Nashville	546	168	191	29.45	30.02	+.02	76.8	−1.0	93	25	87	57	28	67	28	68	64	71	3.83	+0.4	6	4,760	w.	48	e.	2	15	9	7	4.3	0.0	0.0
Lexington	989	193	230	28.97	30.01	.00	74.7	+0.1	93	18	84	55	10	65	27	....	....	....	2.20	−1.4	10	7,908	sw.	48	nw.	1	14	10	7	4.1	0.0	0.0
Louisville	525	219	255	29.44	30.02	+.02	76.4	−0.6	95	17	86	57	11	67	27	65	60	63	1.63	−1.9	5	6,275	ne.	41	sw.	7	15	13	3	4.0	0.0	0.0
Evansville	431	139	175	29.55	30.01	+.02	77.8	+0.8	96	18	88	60	9	68	28	67	62	63	3.08	−0.2	7	6,062	sw.	42	nw.	2	8	21	2	4.5	0.0	0.0
Indianapolis	822	194	230	29.14	30.01	+.01	74.4	+0.8	95	17	84	56	10	65	27	65	61	67	2.45	−0.9	9	6,479	nw.	58	nw.	6	15	14	2	3.5	0.0	0.0
Royal Center	738	11	55	29.21	30.00	.....	71.3	.....	93	15	84	49	27	59	31	....	....	....	1.70	.....	10	4,936	se.	41	nw.	18	9	20	2	5.0	0.0	0.0
Terre Haute	575	96	129	29.37	29.98	.....	75.6	.....	97	17	86	55	10	65	30	65	60	66	2.40	.....	5	5,250	sw.	36	nw.	17	7	20	4	4.8	0.0	0.0
Cincinnati	628	11	51	29.34	30.01	.00	73.7	+0.2	97	17	85	52	10	62	32	....	61	68	5.60	+2.3	9	3,810	ne.	36	nw.	6	14	12	5	4.2	0.0	0.0
Columbus	824	179	222	29.15	30.01	.00	71.4	−1.6	94	18	81	51	10	62	27	63	58	66	1.94	−1.8	9	5,917	n.	48	nw.	7	13	12	6	4.9	0.0	0.0
Dayton	899	181	216	29.04	29.97	.....	72.4	−1.2	94	17	82	52	10	62	29	63	58	65	2.51	−0.5	7	5,475	ne.	39	nw.	25	20	8	3	3.5	0.0	0.0
Elkins	1,947	39	67	28.03	30.04	+.02	66.2	−2.2	87	18	76	42	21	56	38	60	59	88	2.96	−0.7	11	2,388	w.	18	nw.	7	6	13	12	6.3	0.0	0.0
Parkersburg	638	77	84	29.38	30.03	+.02	72.3	−1.0	93	18	82	52	22	62	37	65	62	77	7.44	+3.9	9	2,916	se.	28	nw.	18	13	9	9	5.1	0.0	0.0
Pittsburgh	842	353	410	29.12	30.01	.00	70.8	−2.1	92	17	80	50	21	61	32	62	58	68	2.35	−0.8	9	5,817	sw.	32	sw.	7	10	11	10	5.4	0.0	0.0
Lower Lake Region.							**69.3**	**−0.3**											**69**	**3.41**	**+0.4**											**4.6**		
Buffalo	767	247	280	29.18	29.99	.00	68.2	−0.4	86	14	75	55	10	62	20	62	59	73	4.62	+1.6	8	8,572	sw.	50	sw.	7	10	12	9	5.4	0.0	0.0
Canton	448	10	61	29.49	29.95	.....	66.2	−1.6	87	15	76	43	9	56	28	....	....	....	4.25	+1.6	8	4,801	sw.	35	sw.	25	12	13	6	4.2	0.0	0.0
Oswego	335	76	91	29.61	29.98	−.01	67.9	−0.9	89	18	75	51	9	60	26	62	59	75	3.26	+0.6	8	5,604	s.	28	ne.	20	11	9	11	5.1	0.0	0.0
Rochester	523	86	102	29.44	30.00	+.01	68.8	−0.4	91	16	78	50	9	60	26	61	57	69	2.53	−0.4	8	4,548	sw.	35	w.	18	13	7	11	5.2	0.0	0.0
Syracuse	597	97	113	29.37	30.00	+.01	67.6	−1.0	90	18	76	47	9	59	27	....	....	....	4.87	+1.5	12	5,740	s.	41	nw.	18	8	9	14	6.0	0.0	0.0
Erie	714	130	166	29.24	29.99	−.02	69.8	+0.2	90	18	78	51	21	62	27	62	57	66	2.66	−0.6	8	8,055	nw.	36	sw.	25	16	11	4	3.8	0.0	0.0
Cleveland	762	190	201	29.19	30.00	−.01	69.6	−0.4	92	18	77	51	21	62	23	62	57	66	1.20	−2.0	9	7,378	s.	40	nw.	7	14	10	7	4.5	0.0	0.0
Sandusky	629	62	103	29.33	30.00	−.01	71.4	−0.1	94	18	79	53	21	63	25	....	....	....	2.52	−0.8	5	6,820	sw.	50	n.	7	15	12	4	3.9	0.0	0.0
Toledo	628	208	243	29.34	30.01	+.01	71.2	−0.1	94	16	80	52	9	62	26	62	58	67	4.79	+2.1	8	7,895	sw.	36	w.	7	17	11	3	3.3	0.0	0.0
Fort Wayne	856	113	124	29.10	30.01	.....	71.6	+0.5	95	17	82	53	27	61	28	63	58	66	1.56	.....	9	4,960	e.	31	sw.	18	7	20	4	5.1	0.0	0.0
Detroit	730	218	245	29.23	30.01	.00	70.9	+0.6	95	17	80	51	9	62	24	62	58	67	3.36	+0.6	8	6,122	sw.	39	n.	2	14	13	4	4.0	0.0	0.0
Upper Lake Region.							**67.2**	**+1.0**											**74**	**2.38**	**−0.6**											**4.4**		
Alpena	609	13	92	29.35	30.01	+.01	64.4	+0.3	90	17	74	44	9	55	25	60	57	78	5.14	+1.8	8	6,445	nw.	52	nw.	24	9	18	4	4.7	0.0	0.0
Escanaba	612	54	60	29.33	29.99	.00	64.5	0.0	92	17	72	45	8	56	24	60	58	80	2.18	−1.4	15	5,758	s.	33	n.	7	12	11	8	4.8	0.0	0.0
Grand Haven	632	54	89	29.32	29.99	.00	67.8	+0.2	87	17	77	47	9	59	26	62	59	73	3.02	+0.4	6	5,850	w.	36	nw.	25	17	9	5	4.0	0.0	0.0
Grand Rapids	707	70	87	29.25	30.00	.00	71.2	+1.2	93	16	82	50	9	60	28	62	57	64	2.96	+0.4	11	3,181	w.	31	w.	25	6	15	10	5.5	0.0	0.0
Houghton	684	62	99	29.26	29.98	+.01	64.2	+0.9	90	14	73	45	29	55	30	....	....	....	2.01	−0.9	8	6,650	e.	38	nw.	24	12	12	7	4.7	0.0	0.0
Lansing	878	11	62	29.07	30.00	.....	68.8	+0.2	94	16	81	44	9	56	34	61	58	76	2.42	−0.2	11	2,630	nw.	19	n.	3	9	18	4	4.8	0.0	0.0
Ludington	637	60	66	29.31	30.00	.....	66.2	.....	82	16	74	45	9	59	24	61	58	75	1.93	.....	11	5,703	s.	27	sw.	24	21	7	3	2.9	0.0	0.0
Marquette	734	77	111	29.22	30.01	+.03	64.8	+1.3	93	17	73	46	8	57	26	59	56	75	2.02	−0.8	9	6,428	sw.	38	w.	24	9	12	10	5.4	0.0	0.0
Port Huron	638	70	120	29.31	30.00	.00	68.0	+0.7	94	17	77	45	9	59	25	63	60	77	0.89	−1.7	5	6,206	ne.	36	nw.	25	15	15	1	3.5	0.0	0.0
Saginaw	641	69	77	29.32	30.00	.....	68.5	.....	94	16	80	47	21	58	30	60	56	69	1.79	−1.1	10	4,165	se.	26	sw.	24	12	14	5	4.3	0.0	0.0
Sault Ste. Marie	614	11	52	29.31	30.00	+.01	63.2	+2.6	90	15	73	40	30	53	32	57	54	78	1.64	−1.5	10	4,041	nw.	31	nw.	18	11	14	6	4.7	0.0	0.0
Chicago	823	140	310	29.13	30.00	.00	73.2	+0.4	92	17	80	56	9	67	22	64	60	66	1.45	−1.4	6	6,491	s.	48	nw.	24	19	10	2	3.4	0.0	0.0
Green Bay	617	109	144	29.32	29.98	−.01	69.0	+2.0	92	16	78	47	8	60	23	62	59	76	4.10	+1.0	8	6,271	s.	62	w.	24	10	14	7	5.4	0.0	0.0
Milwaukee	681	125	139	29.26	30.00	.00	70.6	+1.9	93	17	78	51	8	63	24	63	59	70	1.71	−1.1	7	6,115	se.	34	ne.	6	16	12	3	3.8	0.0	0.0
Duluth	1,133	11	47	28.77	29.97	.00	64.2	+1.6	92	15	74	43	29	55	31	59	56	79	2.01	−1.5	9	7,808	ne.	50	nw.	24	11	12	8	4.7	0.0	0.0
North Dakota.							**70.9**	**+4.8**											**62**	**1.14**	**−1.2**											**3.9**		
Moorhead	940	50	58	28.92	29.92	−.04	71.4	+5.3	97	14	84	44	29	59	40	61	55	62	0.74	−2.4	7	5,011	s.	27	n.	24	11	15	5	4.6	0.0	0.0
Bismarck	1,674	8	57	28.19	29.94	.00	72.6	+5.3	100	13	86	47	25	59	41	61	55	60	0.22	−1.8	5	6,216	e.	42	nw.	6	16	13	2	3.5	0.0	0.0
Devils Lake	1,482	11	44	28.37	29.92	−.02	70.0	+4.9	98	13	83	46	25	57	40	60	54	67	1.72	−1.0	9	6,247	se.	40	nw.	24	16	10	5	3.9	0.0	0.0
Ellendale	1,457	10	56	28.41	29.95	.....	71.4	.....	100	23	86	42	29	56	44	....	....	....	0.16	.....	5	8,547	s.	56	n.	24	17	11	3	3.2	0.0	0.0
Grand Forks	835	12	89	.....	.....	.....	69.9	.....	96	13	83	40	29	57	42	....	....	....	2.41	.....	11	.....	se.	32	se.	13	15	11	5	.....	0.0	0.0
Williston	1,878	41	48	27.95	29.88	−.05	69.6	+3.5	98	12	83	41	7	56	40	59	52	58	1.86	+0.6	11	5,456	se.	44	nw.	15	15	10	6	4.3	0.0	0.0
Upper Mississippi Valley.							**74.3**	**+1.6**											**69**	**2.02**	**−1.2**											**4.2**		
Minneapolis	918	102	208	28.97	29.93	.....	73.4	.....	95	17	84	52	29	63	31	....	....	....	1.66	−2.0	8	7,385	se.	55	nw.	24	11	15	5	5.0	0.0	0.0
St. Paul	837	236	261	29.07	29.96	−.01	72.0	+2.6	94	17	82	51	26	62	34	....	....	....	1.31	−2.2	7	7,346	se.	48	nw.	24	11	17	3	4.4	0.0	0.0
La Crosse	714	11	48	29.21	29.96	−.02	71.6	+1.6	95	17	83	49	27	60	32	....	....	....	3.43	0.0	8	2,789	se.	22	nw.	24	14	10	7	4.5	0.0	0.0
Madison	974	70	78	28.97	29.99	.00	71.2	+1.6	92	17	80	51	8	62	25	63	60	72	1.33	−1.9	5	4,955	sw.	33	ne.	28	10	14	7	5.1	0.0	0.0
Wausau	1,247	4	....	28.69	30.02	.....	67.4	.....	91	17	78	44	27	56	32	....	....	....	2.74	.....	8	.....	n.	.....	.....	.....	.....	13	6	12	4.9	0.0	0.0
Charles City	1,015	10	49	28.91	29.97	.00	71.6	+0.9	94	17	83	47	8	61	32	65	62	74	1.99	−1.4	11	3,773	se.	23	w.	17	18	8	5	3.2	0.0	0.0
Davenport	606	71	79	29.34	29.99	+.01	75.3	+2.3	97	24	85	52	9	65	27	65	61	64	0.48	−3.2	11	3,719	sw.	24	nw.	25	14	8	9	4.4	0.0	0.0
Des Moines	861	84	97	29.07	29.96	−.01	74.8	+1.8	97	24	85	53	27	65	28	67	64	74	6.63	+3.0	9	4,166	s.	29	sw.	28	19	5	7	3.7	0.0	0.0
Dubuque	698	81	96	29.26	30.00	+.02	72.5	+0.8	93	24	82	51	9	63	26	65	61	73	1.99	−1.0	6	3,443	s.	27	n.	1	14	13	4	4.0	0.0	0.0
Keokuk	614	64	78	29.33	29.99	+.01	75.8	+1.2	99	24	86	55	9	66	29	67	63	67	3.37	+0.1	9	3,694	s.	24	nw.	18	12	12	7	5.0	0.0	0.0
Cairo	358	87	93	29.61	29.98	−.01	77.6	+0.6	94	18	86	60	9	69	25	68	65	71	0.98	−2.0	4	4,342	n.	22	n.	8	13	7	11	5.0	0.0	0.0
Peoria	609	11	45	29.34	30.01	+.02	74.5	+2.0	98	24	86	47	9	62	35	66	62	71	0.72	−2.2	4	2,834	s.	19	n.	25	21	8	2	2.5	0.0	0.0
Springfield, Ill	644	10	91	29.31	29.97	−.02	76.6	+2.1	100	24	88	54	9	66	32	65	60	64	0.55	−2.2	5	4,848	s.	26	nw.	25	15	12	4	4.0	0.0	0.0
Hannibal	534	74	109	29.42	29.98	.00	76.0	+1.0	100	24	86	51	9	66	37	....	....	....	2.12	−1.3	7	4,864	sw.	30	sw.	6	16	9	6	4.0	0.0	0.0
St. Louis	567	265	303	29.39	29.98	−.01	79.1	+1.8	100	24	88	59	9	70	24	67	62	60	1.79	−0.9	7	7,125	s.	49	sw.	15	13	13	5	4.0	0.0	0.0
Missouri Valley.							**77.2**	**+3.5**											**64**	**1.59**	**−1.8**											**3.5**		
Columbia, Mo	781	11	84	29.17	29.98	+.01	76.6	+1.9	99	24	88	52	9	66	32	....	....	....	3.30	+0.3	8	4,381	se.	44	n.	29	12	13	6	4.1	0.0	0.0
Kansas City	963	161	181	28.96	29.96	−.01	78.7	+2.9	102	24	88	60	27	69	27	68	63	64	0.81	−3.9	5	5,725	s.	41	ne.	21	16	13	2	3.5	0.0	0.0
St. Joseph	967	11	49	28.94	29.94	.....	77.9	.....	102	24	89	55	27	67	33	68	63	68	1.53	.....	7	4,459	se.	28	nw.	25	19	8	4	3.1	0.0	0.0
Springfield, Mo	1,324	98	104	28.62	29.99	+.02	77.0	+2.2	100	24	86	58	27	68	26	67	62	66	2.47	−1.8	7	6,007	se.	35	e.	18	15	13	3	3.2	0.0	0.0
Iola	984	11	50	28.94	29.96	.00	79.4	+3.1	105	24	91	56	27	67	31	....	....	....	3.65	+0.2	10	3,454	s.	19	n.	25	13	15	3	4.1	0.0	0.0
Topeka	987	92	107	.....	.....	.....	79.2	+3.2	106	24	90	55	27	68	32	....	....	....	0.43	−3.9	7	5,733	s.	31	s.	21	19	9	3	3.2	0.0	0.0
Drexel	1,299	10	53	28.59	29.94	.....	75.6	.....	98	24	87	51	25	64	36	....	....	....	1.31	.....	6	5,849	s.	30	e.	21	17	11	3	3.6	0.0	0.0
Lincoln	1,189	11	84	28.70	29.93	−.02	78.5	+4.1	104	24	91	54	8	66	38	67	62	62	0.69	−3.0	5	5,741	s.	36	n.	24	14	12	5	4.0	0.0	0.0
Omaha	1,105	115	122	28.80	29.95	−.01	77.7	+3.3	102	24	88	57	8	68	34	68	64	68	1.01	−2.6	7	4,393	se.	36	n.	24	19	10	2	3.0	0.0	0.0
Valentine	2,598	47	54	27.29	29.95	+.01	75.2	+3.9	101	31	89	48	25	62	48	63	57	61	0.42	−2.4	8	5,855	s.	32	n.	24	19	7	5	3.2	0.0	0.0
Sioux City	1,135	94	164	28.76	29.94	−.01	75.4	+2.8	97	17	86	51	8	65	34	66	62	67	2.92	−0.1	9	6,900	s.	43	ne.	20	15	11	5	3.8	0.0	0.0
Huron	1,306	59	74	28.58	29.94	−.01	75.1	+5.7	100	23	88	50	29	62	38	63	57	62	0.39	−2.2	7	5,995	se.	46	n.	24	17	11	3	3.1	0.0	0.0
Pierre	1,572	70	75	28.29	29.91	−.03	76.6	+3.8	99	23	89	51	27	64	47	65	59	62	2.03	0.0	4	5,675	e.	47	nw.	2	21	5	5	3.1	0.0	0.0
Yankton	1,233	49	57	28.64	29.92	−.03	76.6	+4.6	102	31	88	51	8	65	40	....	....	....	0.96	−2.2	7	4,442	s.	30	nw.	17	14	13	4	4.1	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, August, 1922*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean relative humidity.	Precipitation.			Wind.											Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. +mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean temperature of the dew point.			Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.									
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F*			° *F.*		° *F*	° *F.*	° *F.*	° *F.*		*In.*	*In.*		*Miles.*											*0–10*	*In.*	*In.*
Northern Slope.							**70.4**	**+3.9**										**56**	**1.35**	**+0.1**													**3.6**		
Billings	3,140	5					74.2		103	12	93	46	25	55	53				0.32		5													0.0	0.0
Havre	2,505	11	44	27.33	29.91	.00	70.0	+4.6	96	3	84	45	25	56	41	58	50	59	1.70	+0.4	5	4,829	e.	39	sw.	15	19	12	0	3.0			3.0	0.0	0.0
Helena	4,110	87	112	25.83	29.93	−.01	68.6	+2.5	91	18	82	46	16	55	35	55	46	52	0.94	+0.2	11	5,279	sw.	42	sw.	19	11	14	6	4.7			4.7	0.0	0.0
Kalispell	2,973	48	56	26.91	29.90	−.03	65.8	+2.9	93	3	80	42	16	52	40	53	44	52	0.76	−0.1	8	3,933	nw.	26	w.	19	13	13	5	3.8			3.8	0.0	0.0
Miles City	2,371	26	48	27.44	29.93	.00	76.0	+4.5	100	12	91	50	25	62	45	61	52	51	0.48	−0.6	4	4,146	ne.	33	s.	15	21	7	3	2.7			2.7	0.0	0.0
Rapid City	3,259	50	58	26.62	29.95	+.02	73.4	+4.6	96	12	86	52	7	61	43	60	53	53	1.22	−0.9	7	4,628	w.	33	n.	24	20	7	4	3.3			3.3	0.0	0.0
Cheyenne	6,088	84	101	24.14	29.97	+.05	69.0	+3.2	90	12	82	50	7	58	37	56	49	59	2.16	+0.7	15	7,168	w.	41	w.	21	12	17	2	4.1			4.1	0.0	0.0
Lander	5,372	60	68	24.73	29.94	+.02	70.6	+4.9	91	24	85	48	16	56	42	56	47	50	1.04	+0.5	8	3,648	sw.	48	sw.	31	12	17	2	4.5			4.5	0.0	0.0
Sheridan	3,790	10	47	26.13	29.95	.....	71.1	.....	98	12	87	46	18	56	44	58	51	57	1.65	.....	11	3,024	s.	37	sw.	14	20	9	2	3.3			3.3	0.0	0.0
Yellowstone Park	6,200	11	48	24.00	29.98	−.05	63.0	+2.1	85	18	77	40	17	49	42	51	44	59	1.60	+0.6	15	5,558	s.	44	sw.	20	12	13	6	4.6			4.6	0.0	0.0
North Platte	2,821	11	51	27.12	29.98	−.04	76.8	+6.0	102	31	91	48	27	62	46	64	60	66	2.26	−0.2	7	4,163	se.	25	se.	3	27	4	0	2.0			2.0	0.0	0.0
Middle Slope.							**79.4**	**+4.1**										**58**	**1.43**	**−1.0**													**3.6**		
Denver	5,292	106	113	24.83	29.98	+.06	74.2	+3.5	92	31	86	57	8	62	32	59	52	55	1.50	+0.2	12	5,219	s.	36	n.	8	11	19	1	4.0			4.0	0.0	0.0
Pueblo	4,685	80	86	25.36	29.94	+.03	76.5	+4.4	98	24	91	56	27	62	38	60	52	54	0.69	−0.9	9	4,493	nw.	41	e.	4	9	22	0	4.6			4.6	0.0	0.0
Concordia	1,392	50	58	28.50	29.93	−.02	80.6	+4.1	107	24	93	57	8	68	35	67	61	59	0.88	−1.9	3	4,818	s.	32	sw.	24	15	15	1	3.8			3.8	0.0	0.0
Dodge City	2,509	11	51	27.42	29.95	+.02	80.0	+3.5	104	23	93	56	27	67	35	65	59	58	3.19	+0.6	7	6,268	se.	36	nw.	3	24	7	0	1.9			1.9	0.0	0.0
Wichita	1,358	139	158	28.52	29.92	−.03	80.8	+3.3	105	22	91	60	26	70	29	68	63	61	2.12	−1.0	6	8,416	s.	38	n.	25	18	11	2	3.4			3.4	0.0	0.0
Altus	1,410	5					85.4	.....	109	24	100	63	9	70	38				0.41	.....	2		se.				20	6	5					0.0	0.0
Broken Arrow	765	11	52	29.16	29.98	.....	80.2	.....	104	24	91	61	26	70	28				1.99	.....	8	6,430	s.	32	nw.	7	13	12	6	4.3			4.3	0.0	0.0
Muskogee	652	4					82.9	.....	106	22	96	59	9	69	33				1.80	.....	7		w.				20	6	5					0.0	0.0
Oklahoma City	1,214	10	47	28.70	29.94	.00	84.4	+5.9	107	24	96	62	9	72	29	69	63	58	0.19	−3.0	3	6,750	s.	29	s.	12	20	10	1	3.1			3.1	0.0	0.0
Southern Slope.							**83.1**	**+4.0**										**48**	**0.32**	**−1.9**													**3.2**		
Abilene	1,738	10	52	28.16	29.92	.00	85.0	+3.8	104	3	97	67	10	73	28	67	59	49	0.20	−1.8	2	5,537	s.	29	nw.	7	13	12	6	4.5			4.5	0.0	0.0
Amarillo	3,676	10	49	26.31	29.94	+.02	81.6	+7.0	104	3	95	61	9	68	33	67	58	53	0.78	−2.0	4	7,068	s.	42	se.	6	26	5	0	2.5			2.5	0.0	0.0
Del Rio	944	64	71	28.96	29.92	+.02	86.2	+2.2	100	27	96	70	13	76	25				0.15	−2.4	2	5,732	se.	33	e.	19	17	11	3	3.4			3.4	0.0	0.0
Roswell	3,566	75	85	26.38	29.90	+.02	79.6	+3.0	100	26	94	61	15	66	35	61	50	43	0.15	−1.3	4	5,029	s.	36	ne.	26	20	11	0	2.6			2.6	0.0	0.0
Southern Plateau.							**78.8**	**+1.4**										**49**	**0.64**	**−0.4**													**3.2**		
El Paso	3,762	110	133	26.18	29.83	−.01	82.6	+4.0	99	5	94	67	28	72	28	63	52	40	0.27	−1.4	6	6,439	se.	39	sw.	11	18	13	0	2.7			2.7	0.0	0.0
Santa Fe	7,013	38	53	23.39	29.90	+.01	70.7	+3.7	90	24	83	54	21	58	30	55	46	52	1.85	−0.5	11	3,665	e.	24	ne.	17	11	19	1	4.0			4.0	0.0	0.0
Flagstaff	6,908	10	59	23.48	29.90	+.06	64.6	+1.8	85	26	78	45	2	51	37	53	....	66	3.24	.....	14	4,573	w.	27	e.	27	10	17	4	.....			....	0.0	0.0
Phoenix	1,108	11	81	28.66	29.78	−.01	89.4	+0.4	110	29	102	72	16	76	34	71	63	49	0.57	−0.4	5	3,775	w.	32	se.	15	18	11	2	3.5			3.5	0.0	0.0
Yuma	141	9	54	29.64	29.78	+.02	91.2	+0.8	113	29	105	70	14	78	38	74	67	54	0.12	−0.2	2	3,847	s.	30	se.	27	15	14	2	3.5			3.5	0.0	0.0
Independence	3,957	9	41	25.96	29.91	+.10	74.3	−2.1	96	7	90	48	15	59	40	55	39	34	0.39	+0.3	4	4,381	se.	33	se.	27	24	5	2	2.1			2.1	0.0	0.0
Middle Plateau.							**71.6**	**+0.2**										**47**	**1.32**	**+0.6**													**3.4**		
Reno	4,552	74	81	25.48	29.90	+.06	67.6	+0.6	94	7	85	40	22	51	43	50	36	39	0.01	−0.2	1	5,077	w.	28	w.	9	23	6	2	2.0			2.0	0.0	0.0
Tonopah	6,090	12	20	24.16	29.96	.....	70.3	.....	90	7	82	49	15	58	33	54	49	44	0.77	+0.4	6	5,047	se.	32	nw.	3	21	10	0	3.0			3.0	0.0	0.0
Winnemucca	4,344	18	56	25.62	29.94	+.06	67.8	−3.0	95	8	86	41	17	50	51	51	38	44	0.91	+0.7	5	4,272	sw.	50	s.	27	23	4	4	2.5			2.5	0.0	0.0
Modena	5,479	10	43	24.68	29.91	+.05	69.6	+1.0	93	7	84	48	15	56	41	56	47	55	2.41	+0.6	11	7,215	sw.	44	s.	22	16	10	5	4.0			4.0	0.0	0.0
Salt Lake City	4,360	163	203	25.65	29.92	+.01	76.2	+1.7	93	12	86	59	31	66	26	60	51	47	1.85	+1.1	13	3,970	se.	60	nw.	31	14	11	6	4.5			4.5	0.0	0.0
Grand Junction	4,602	60	68	25.44	29.95	+.05	77.0	+0.9	96	12	90	59	31	64	34	61	54	52	2.00	+1.0	13	4,343	se.	37	w.	31	10	15	6	5.1			5.1	0.0	0.0
Northern Plateau.							**72.4**	**+1.9**										**47**	**1.25**	**+0.8**													**4.2**		
Baker	3,471	48	53	26.44	29.96	+.01	67.2	+2.3	96	27	82	40	13	52	43	54	45	52	1.06	+0.7	8	4,366	se.	25	se.	9	13	15	3	4.5			4.5	0.0	0.0
Boise	2,739	78	86	27.11	29.90	−.03	74.4	+2.6	99	26	89	48	20	60	41	58	46	42	1.13	+1.0	6	3,688	se.	29	sw.	8	19	8	4	3.4			3.4	0.0	0.0
Lewiston	757	40	48	29.11	29.90	−.05	75.7	+2.2	104	26	91	52	20	60	46				1.21	+0.8	7	2,352	w.	26	nw.	19	13	11	7	4.6			4.6	0.0	0.0
Pocatello	4,477	60	68	25.50	29.92	.00	71.6	+1.1	94	18	84	48	16	59	41	57	48	50	2.20	+1.6	14	5,530	se.	38	sw.	30	14	11	6	4.3			4.3	0.0	0.0
Spokane	1,929	101	110	27.92	29.92	−.03	71.0	+2.9	98	1	85	49	15	57	41	56	44	45	0.65	+0.2	7	3,491	sw.	28	sw.	19	15	8	8	4.5			4.5	0.0	0.0
Walla Walla	991	57	65	28.86	29.92	−.04	74.2	+0.4	102	29	86	51	20	62	34	59	48	44	1.25	+0.8	6	3,337	sw.	21	w.	19	16	9	6	4.0			4.0	0.0	0.0
North Pacific Coast Region.							**62.0**	**−0.3**										**79**	**1.35**	**+0.8**													**3.8**		
North Head	211	11	56	29.81	30.03	.00	57.4	−0.5	76	24	60	49	3	54	23	56	56	95	2.76	+2.2	9	11,218	n.	54	s.	10	3	9	19	7.5			7.5	0.0	0.0
Port Angeles	29	8	53	30.02	30.04	.....	58.4	.....	84	24	66	44	22	50	33				0.48	−0.2	8	4,029	sw.	19	sw.	26	8	12	11	5.7			5.7	0.0	0.0
Seattle	125	215	250	29.90	30.03	+.03	62.7	−0.4	84	25	70	52	5	55	28	57	53	73	1.17	+0.7	7	5,399	s.	26	s.	15	8	13	10	5.6			5.6	0.0	0.0
Tacoma	213	113	120	29.82	30.04	+.02	63.2	+0.2	85	25	72	48	22	55	26				1.52	+0.8	7	3,852	n.	20	w.	26	4	13	14	6.5			6.5	0.0	0.0
Tatoosh Island	85	9	57	29.93	30.02	+.02	55.2	−0.1	66	24	59	46	9	52	15	54	53	95	2.54	+0.4	9	7,495	s.	44	s.	26	6	5	20	7.5			7.5	0.0	0.0
Yakima	1,071	5					71.0	.....	98	1	87	42	20	55	43				0.18	.....			nw.				12	5	14					0.0	0.0
Medford	1,425	4					68.7	.....	96	2	87	44	19	51	49				T.	.....	0		nw.				18	4	9					0.0	0.0
Portland, Oreg	153	68	106	29.84	30.00	−.01	67.2	+0.5	92	24	77	52	22	57	31	60	55	68	2.06	+1.4	7	3,870	nw.	24	sw.	10	17	6	8	4.2			4.2	0.0	0.0
Roseburg	510	9	57	29.47	30.02	+.02	66.6	−1.4	93	25	80	46	13	53	39	57	50	63	0.32	0.0	5	2,286	n.	14	nw.	20	16	12	3	3.5			3.5	0.0	0.0
Middle Pacific Coast Region.							**64.2**	**0.0**										**64**	**0.06**	**0.0**													**3.3**		
Eureka	62	73	89	30.00	30.07	+.07	56.9	+1.1	70	11	62	47	9	52	20	54	52	87	0.03	−0.1	2	3,871	nw.	21	n.	13	6	17	8	5.7			5.7	0.0	0.0
Point Reyes	490	7	18	29.42	29.94	.....	54.0	−0.5	66	24	58	47	2	50	14				0.00	.....	0	20,190	nw.	60	nw.	13	7	8	16	6.6			6.6	0.0	0.0
Red Bluff	332	50	56	29.53	29.87	+.01	77.0	−2.7	104	6	92	54	24	62	37	60	46	39	0.30	+0.3	2	3,854	se.	20	n.	13	28	3	0	1.3			1.3	0.0	0.0
Sacramento	69	106	117	29.82	29.89	+.04	72.8	−0.1	102	6	88	51	22	57	42	59	49	49	T.	0.0	0	6,142	s.	24	s.	21	27	4	0	1.2			1.2	0.0	0.0
San Francisco	155	208	243	29.79	29.96	+.04	60.4	+2.4	81	31	67	51	5	54	23	55	52	82	T.	0.0	0	7,951	w.	34	w.	20	19	11	1	3.0			3.0	0.0	0.0
San Jose	141	12	110	29.81	29.96	.....	65.0	.....	91	6	79	46	19	51	42				T.	0.0	0	4,199	nw.	21	nw.	31	26	3	2	2.1			2.1	0.0	0.0
South Pacific Coast Region.							**72.4**	**+1.2**										**63**	T.	**0.0**													**1.9**		
Fresno	327	89	98	29.53	29.87	+.05	79.1	−2.1	103	7	95	55	24	63	36	59	42	34	T.	0.0	0	6,424	nw.	27	nw.	21	29	1	1	0.6			0.6	0.0	0.0
Los Angeles	338	159	191	29.54	29.90	+.02	73.3	+2.2	95	27	84	57	21	63	26	63	58	69	0.00	0.0	0	3,603	sw.	15	sw.	14	25	5	1	1.8			1.8	0.0	0.0
San Diego	87	62	70	29.80	29.88	−.01	70.7	+2.0	84	26	76	62	15	65	16	65	62	80	T.	0.0	0	4,306	nw.	19	nw.	23	15	13	3	3.7			3.7	0.0	0.0
San Luis Obispo	201	32	40	29.73	29.95	+.01	66.4	+2.9	97	27	81	45	22	52	42	55	50	69	0.00	0.0	0	2,879	nw.	17	ne.	19	39	1	0	1.4			1.4	0.0	0.0
West Indies.																																				
San Juan, P. R	82	8	54	29.92	30.00	.....	79.6	.....	87	17	84	72	9	75	14	.....	.....	.....	S. 16	+0.8	23	9,587	e.	39	e.	9	10	18	3	4.7			4.7	0.0	0.0
Panama Canal.																																				
Balboa Heights	118	7	97	29.72	29.84	.00	80.5	+0.3	91	2	86	72	25	74	17	75	74	85	1.46	−6.3	13	5,390	nw.	23	nw.	10	0	18	13	7.2			7.2	0.0	0.0
Colon	33	7	97	29.81	29.84	−.01	81.4	+1.4	91	27	87	74	25	76	16	76	75	84	14.53	−0.5	23	7,011	w.	31	sw.	22	1	8	22	8.0			8.0	0.0	0.0
Alaska.																																				
Juneau	80	11	54	29.89	29.98	.....	55.0	.....	73	6	62	36	31	49	27	52	50	86	9.20	.....	24	3,997	s.	28	se.	30	2	3	26	8.6			8.6	0.0	0.0

TABLE 2.—*Data furnished by the Canadian Meteorological Service, August, 1922.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*In.*	*In.*	*In.*
St. Johns, N. S.	125												
Sydney, C. B. I.	48	29.98	30.03	+.08	65.4	+2.1	73.3	57.6	83	44	7.94	+4.32	0.0
Halifax, N. S.	88	29.90	30.00	+.04	64.9	+1.3	72.0	57.9	83	48	3.64	−0.71	0.0
Yarmouth, N. S.	65	29.91	29.98	+.01	61.0	+0.8	68.0	54.1	79	46	7.82	+3.81	0.0
Charlottetown, P. E. I.	38												
Chatham, N. B.	28	29.93	29.96	+.03	64.6	+1.4	74.2	55.1	85	45	5.91	+1.87	0.0
Father Point, Que.	20	29.90	29.92	+.01	54.9	−0.7	63.8	45.9	80	36	2.30	−0.75	0.0
Quebec, Que.	296	29.64	29.96	+.03	64.0	+0.9	73.2	54.7	86	44	2.10	−1.73	0.0
Montreal, Que.	187	29.74	29.94	+.01	66.4	0.0	75.0	57.8	83	48	3.86	+0.29	0.0
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.71	29.97	+.01	67.4	+2.6	79.0	55.8	93	44	2.06	−0.97	0.0
Kingston, Ont.	285	29.66	29.96	−.02	67.8	+0.8	75.3	60.3	85	48	1.49	−0.89	0.0
Toronto, Ont.	379	29.58	29.97	−.02	69.0	+3.0	80.1	57.9	93	48	1.47	−1.29	0.0
Cochrane, Ont.	930				59.1		70.4	47.8	87	35	2.01		0.0
White River, Ont.	1,244	28.65	29.95	−.01	57.1	+1.4	72.2	43.5	88	26	1.52	−1.78	0.0
Port Stanley, Ont.	592	29.38	30.01	+.01	66.3	+0.4	76.0	56.7	85	44	3.40	+0.98	0.0
Southampton, Ont.	656				63.8	0.0	72.7	54.9	84	41	2.32	+0.07	0.0
Parry Sound, Ont.	688	29.29	29.97	−.01	65.7	+2.2	77.1	54.3	88	42	1.49	−1.23	0.0
Port Arthur, Ont.	644	29.28	29.99	+.03	63.7	+4.2	74.2	53.2	92	39	1.86	−0.89	0.0
Winnipeg, Man.	760	29.10	29.91	−.03	67.4	+4.0	79.7	55.2	90	44	1.35	−1.32	0.0
Minnedosa, Man.	1,690	28.14	29.92	−.02	64.5	+5.1	76.5	52.5	90	36	2.31	+0.21	0.0
Le Pas, Man.	860				63.9		77.2	50.6	95	40	1.80		0.0
Qu'Appelle, Sask.	2,115	27.68	29.89	−.01	65.3	+3.8	78.2	52.4	90	39	3.44	+1.80	0.0
Medicine Hat, Alb.	2,144	27.60	29.80	−.12	70.4	+4.7	84.8	56.1	99	44	1.08	−0.59	0.0
Moose Jaw, Sask.	1,759				66.7		81.2	52.3	94	40	1.97		0.0
Swift Current, Sask.	2,392	27.36	29.93	.00	65.9	+1.9	80.0	51.9	94	40	1.87	−0.04	0.0
Calgary, Alb.	3,428												
Banff, Alb.	4,521	25.42	29.91	.00	58.0	+1.7	73.2	42.9	88	34	2.24	−0.29	0.0
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.36	29.91	−.01	63.8	+4.9	76.4	51.3	94	38	2.99	+0.84	0.0
Battleford, Sask.	1,592	28.16	29.87	−.04	65.2	+2.6	77.9	52.5	99	38	3.74	+1.38	0.0
Kamloops, B. C.	1,262	28.69	29.95	+.04	67.7	−0.9	80.4	55.1	96	48	1.36	+0.27	0.0
Victoria, B. C.	230	29.74	29.99	−.02	59.3	+0.6	66.5	52.1	82	48	0.69	+0.09	0.0
Barkerville, B. C.	4,180	25.70	29.97	+.07	54.4	−1.9	66.2	42.6	74	35	1.78	−1.32	0.0
Hamilton, Bermuda	151	30.03	30.19	+.09	79.5	−0.1	85.4	73.6	88	68	3.87	−2.21	0.0
LATE REPORTS FOR JULY, 1922.													
Sydney, C. B. I.	48	30.00	30.05	+.12	62.4	+0.1	70.9	53.9	84	44	6.88	+3.23	0.0
Halifax, N. S.	88	29.92	30.02	+.06	63.2	−0.2	70.4	56.0	81	48	9.04	+4.99	0.0
Yarmouth, N. S.	65	29.95	30.02	+.07	59.7	+0.2	66.7	52.8	79	48	7.37	+3.75	0.0
Charlottetown, P. E. I.	38	29.95	30.00	+.10	64.8	+0.7	71.3	58.3	83	49	4.31	+0.82	0.0
Chatham, N. B.	28	29.96	29.99	+.11	66.3	+1.3	77.3	55.4	90	43	1.98	−2.21	0.0
Calgary, Alb.	3,428	26.49	30.01	+.11	62.5	+1.9	79.0	46.2	91	38	1.99	−0.69	0.0
Banff, Alb.	4,521	25.47	29.97	+.07	58.2	+1.6	73.9	42.5	85	33	0.72	−2.52	0.0
Medicine Hat, Alb.	2,144	27.66	29.86	−.01	71.4	+3.6	88.3	54.6	97	44	1.15	−0.94	0.0
Barkerville, B. C.	4,180	25.78	30.07	+.16	53.6	−1.5	66.6	40.7	74	33	1.75	−1.27	0.0
Hamilton, Ber.	151	30.11	30.27	+.13	78.5	−0.2	84.8	72.2	88	69	2.95	−1.49	0.0

SEISMOLOGICAL REPORTS FOR AUGUST, 1922.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, October 3, 1922.]

TABLE 1.—*Noninstrumental earthquake reports, August, 1922.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1922.	*H. m.*		° ′	° ′			*Sec.*			
Aug. 6	3 30	Eureka	40 48	124 10	3	1	3	None	Felt by many	J. M. Jones.
	5 40	do	40 48	124 10	4	1	6	do	do	Do.
	5 45	Ruth	40 20	123 20	3	1		do		I. McNeil.
18	5 05	Spreckels	36 38	121 36	3	2	5, 10	do	Felt by several	W. S. Suttie.
	5 12	Paso Robles	35 40	120 15	4–5	Several.		Faint	Felt by many	E. J. Nye.
		Coalinga	36 00	120 15	3	1		None	Felt by several	Union Oil Co.
	5 13	Atascadero	35 20	120 30	3	1		do	do	Atascadero Estates, Inc
		San Luis Obispo	35 13	120 45	5	2	2 *ca.*	do	Felt by many	J. E. Hissong.
	5 15	Dudley	35 45	120 00	4	1	20	do	Felt by several	L. J. Heyd.
		Paso Robles	35 40	120 15	5	1	10	Rumbling	Felt by many	Anna Z. Campbell.
	5 20	Los Alamos	34 45	120 15	3	1		None		H. R. Geve.
	6 13	Eureka	40 48	124 10	3	1	3	do	Felt by many	J. M. Jones.
20	21 14	Atascadero	35 20	120 30	3	1		do	Felt by several	Atascadero Estates, Inc.
		SOUTH CAROLINA.								
8	9 25	Summerville	33 05	80 15	2				do	Mrs. Wm. Robertson.

TABLE 2.—*Instrumental seismological reports, August, 1922.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols and description of stations, see REVIEW for January, 1922.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
ALASKA. *U. S. C. & G. S. Magnetic Survey, Sitka.*								
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 11	.....	eL_E	13 55 27	20	.....	.....	.....	
		eL_N	13 56 12	20	.....	.....	.....	
		M_E	13 59 33	16	*100	.....	.....	
		M_N	13 57 26	18	.....	*100	.....	
		F_E	14 07 ..	.....	.....	.....	.....	
		F_N	14 11 ..	.....	.....	.....	.....	
13	.....	eL_E	0 52 00	30	.....	.....	.....	
		eL_N	0 52 50	.....	.....	.....	.....	
		eL_N	1 01 54	20	.....	.....	.....	
		M_E	0 55 07	28	*100	.....	.....	
		M_N	1 03 17	20	.....	*200	.....	
		F_E	1 07 ..	.....	.....	.....	.....	
		F_N	1 14 ..	.....	.....	.....	.....	
ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*								
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 18	.....	e_E	5 16 41	.....	.....	.....	.....	
		e_N	5 16 30	.....	.....	.....	.....	
		M_E	5 17 55	.....	.....	.....	.....	
		M_N	5 17 30	4	.....	10	.....	
		C_E	5 19 33	.....	.....	.....	.....	
		F_E	5 21 ..	.....	.....	.....	.....	
		F_N	5 23 ..	.....	.....	.....	.....	
30	.....	e_E	22 46 55	12	.....	.....	.....	
		e_N	22 46 13	.....	.....	.....	.....	
		e_N	22 47 39	.....	.....	.....	.....	
		M_E	22 47 20	10	28	.....	.....	
		M_N	22 49 41	10	.....	14	.....	
		F_E	22 56 ..	.....	.....	.....	.....	
		F_N	22 53 ..	.....	.....	.....	.....	
CALIFORNIA. *Theosophical University, Point Loma.*								
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 1	.....	.....	.....	.....	100	100	.....	Tremors during preceding 24 hours.
4	.....	.....	.....	.....	50	50	.....	
5	.....	.....	.....	.....	75	100	.....	
6	.....	.....	.....	.....	50	75	.....	
7	.....	.....	.....	.....	50	50	.....	
31	.....	.....	.....	.....	50	50	.....	
DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*								
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 11	.....	S?	8 42 44	.....	.....	.....	.....	Barely perceptible.
		I	8 58 ..	.....	.....	.....	.....	
		F	9 15 *ca*	.....	.....	.....	.....	
13	.....	S	0 32 50	.....	.....	.....	.....	
		eL	0 48 00	.....	.....	.....	.....	
		L	0 51 ..	20	.....	.....	.....	
		F	1 10 *ca*	.....	.....	.....	.....	
16	.....	.....	.....	.....	.....	.....	.....	Sheets illegible.
18	.....	e	5 31 12	.....	.....	.....	.....	
		F	5 37 *ca*	.....	.....	.....	.....	
25	.....	.....	.....	.....	.....	.....	.....	Do.
30	.....	e	22 58 47	.....	.....	.....	.....	
		F	23 06 ..	.....	.....	.....	.....	
HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*								
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 3	.....	e_N	10 05 ..	.....	.....	.....	.....	Very slight. E record lost through overlapping of traces.
		F_N	10 16 ..	.....	.....	.....	.....	
5	.....	e	16 02 00	.....	.....	.....	.....	Nothing definite.
		F_E	16 13 ..	.....	.....	.....	.....	
		F_N	16 08 ..	.....	.....	.....	.....	

* Trace amplified.

13352—22——5

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu*—Contd.								
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Aug. 6	.....	e_E	1 20 09	.....	.....	.....	.....	
		e_N	1 20 01	.....	.....	.....	.....	
		eL_E	1 21 15	.....	.....	.....	.....	
		eL_N	1 21 01	.....	.....	.....	.....	
		M_E	1 22 28	10	4	.....	.....	
		M_N	1 22 28	9	.....	7	.....	
		F_E	1 30 ..	.....	.....	.....	.....	
		F_N	1 32 ..	.....	.....	.....	.....	
7	.....	O	12 33 28	.....	.....	.....	4,050	
		P_E?	12 40 25	.....	.....	.....	.....	P_E Doubtful.
		P_N	12 40 50	.....	.....	.....	.....	
		$PR1_N$	12 42 10	.....	.....	.....	.....	
		S_N	12 46 40	.....	.....	.....	.....	
		$SR1_E$	12 48 55	.....	.....	.....	.....	
		$SR1_N$	12 48 38	.....	.....	.....	.....	
		L_E	12 51 35	.....	.....	.....	.....	
		L_N	12 50 31	.....	.....	.....	.....	
		L_N	12 52 22	.....	.....	.....	.....	
		M_E	12 53 22	13	14	.....	.....	
		M_N	12 53 59	13	.....	12	.....	
		F_E	13 28 ..	.....	.....	.....	.....	
		F_N	13 18 ..	.....	.....	.....	.....	
11	.....	O	13 41 03	.....	.....	.....	3,400	
		S	13 52 45	.....	.....	.....	.....	
		L_E	13 55 54	.....	.....	.....	.....	
		L_N	13 55 59	.....	.....	.....	.....	
		M_E	13 57 32	13	14	.....	.....	
		M_N	13 57 36	13	.....	14	.....	
		F	14 38 ..	.....	.....	.....	.....	
13	.....	e_E	1 02 ..	25	.....	.....	.....	Nothing definite on E.
		e_N	1 05 ..	25	.....	.....	.....	
		$M1_N$	1 23 16	20	.....	21	.....	
		$M2_N$	2 23 ..	.....	.....	.....	.....	
		F_E	2 28 ..	.....	.....	.....	.....	
		F_N	2 37 ..	.....	.....	.....	.....	
14	.....	e	11 55 40	.....	.....	.....	.....	Very slight.
		F_E	12 07 ..	.....	.....	.....	.....	
		F_N	12 15 ..	.....	.....	.....	.....	
16	.....	O	15 55 58	.....	.....	.....	5,080	
		PR1	16 06 21	2	.....	.....	.....	
		S	16 11 18	.....	.....	.....	.....	
		$SR1_E$	16 14 53	.....	.....	.....	.....	
		$SR1_N$	16 14 43	9	.....	.....	.....	
		L1	16 17 20	24	.....	.....	.....	
		$L2_E$	16 18 04	.....	.....	.....	.....	
		$L2_N$	16 18 08	.....	.....	.....	.....	
		M_E	16 17 21	24	66	.....	.....	
		M_N	16 17 25	20	.....	39	.....	
		F	16 25 ..	.....	.....	.....	.....	
18	.....	e_N	5 27 40	.....	.....	.....	.....	Very slight.
		F_N	5 29 50	.....	.....	.....	.....	
18	.....	e_E	20 58 12	15	.....	.....	.....	Nothing definite.
		e_N	20 58 03	.....	.....	.....	.....	
		F_E	21 25 ..	.....	.....	.....	.....	
		F_N	21 13 ..	.....	.....	.....	.....	
25	.....	O	11 43 27	.....	.....	.....	5,700	
		P	11 52 40	.....	.....	.....	.....	
		S_E	12 00 00	.....	.....	.....	.....	
		$SR1_N$	12 04 22	.....	.....	.....	.....	
		L_E	12 06 30	.....	.....	.....	.....	
		$L1_N$	12 07 38	.....	.....	.....	.....	
		$L2_N$	12 10 00	.....	.....	.....	.....	
		M_E	12 10 20	10	8	.....	.....	
		M_N	12 10 24	10	.....	10	.....	
		F_E	12 37 ..	.....	.....	.....	.....	
		F_N	12 32 ..	.....	.....	.....	.....	
25	.....	O	19 45 26	.....	.....	.....	10,150	
		P_N	19 58 35	.....	.....	.....	.....	Maximum occurs during SR1. L very weak. Interpretation doubtful. E record lost through overlapping of traces.
		eS_N	20 09 40	.....	.....	.....	.....	
		$eSR1_N$	20 16 22	.....	.....	.....	.....	
		$eSR2_N$	20 21 30	.....	.....	.....	.....	
		L_N?	20 25 30	.....	.....	.....	.....	
		M_N	20 16 55	20	.....	4	.....	
		F	20 27 ..	.....	.....	.....	.....	
26	.....	e_N	2 44 50	.....	.....	.....	.....	Very slight.
		F_N	2 51 ..	.....	.....	.....	.....	

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu*—Contd.

1922.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 26	.....	O.....	6 35 49	.....	.....	.....	2,690	
		P_E.....	6 41 15	.....	.....	.....	.....	Nothing definite on N. Interpretation doubtful.
		P_N.....	6 41 24	.....	.....	.....	.....	
		e_E.....	6 43 45	.....	.....	.....	.....	
		S_E.....	6 45 35	.....	.....	.....	.....	
		L_E.....	6 47 15	.....	.....	.....	.....	
		M_E.....	6 49 58	12	12	.....	.....	
		M_N.....	6 54 29	.....	.....	9	.....	
		F_E.....	7 06 ..	.....	.....	.....	.....	
		F_N.....	7 23 ..	.....	.....	.....	.....	
29	.....	M_E.....	17 56 ..	16	8	.....	.....	Beginning lost in changing traces. E. record lost through overlap of traces.
		F_N.....	18 10 ..	.....	.....	.....	.....	
30	.....	e_E.....	10 49 40	.....	.....	.....	.....	
		e_E.....	11 02 40	.....	.....	.....	.....	Activity on N. barely perceptible.
		eL_E.....	11 07 40	18	.....	.....	.....	
		M_E.....	11 09 00	18	3	.....	.....	
		F_E.....	11 22 ..	.....	.....	.....	.....	
30	.....	e_E.....	23 03 40	.....	.....	.....	.....	E. record very faint.
		e_N.....	23 03 56	.....	.....	.....	.....	
		M_N.....	23 07 27	8	.....	6	.....	
		F_E.....	23 08 ..	.....	.....	.....	.....	
		F_N.....	23 10 ..	.....	.....	.....	.....	

Periods of pendulums, 12 sec.; sensitivity before Aug. 17, E., 0.193 mm; N. 0.201 mm.; after Aug. 17 E. 0.174 mm.; N. 0.199 mm.; damping ratio, 20.1; multiplication, 150.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 4	.....	e.....	14 09 13	.....	.....	.....	.....	
		L.....	14 09 40	12	.....	.....	.....	Decrease rapidly in period and amplitude.
		F.....	14 20 ..	.....	.....	.....	.....	
11	.....	P?.....	8 32 31	.....	.....	.....	.....	
		S.....	8 42 17	.....	.....	.....	.....	
		L.....	8 56 30	45	.....	.....	.....	
		L.....	9 00 ..	30	.....	.....	.....	
		L.....	9 07 ..	20	.....	.....	.....	
		L.....	9 10 ..	15	.....	.....	.....	
		F.....	9 45 *ca*	.....	.....	.....	.....	
11	.....	P?.....	13 56 40	.....	.....	.....	.....	
		S?.....	14 03 33	.....	.....	.....	.....	
		L.....	14 13 ..	15	.....	.....	.....	
		F.....	16 05 *ca*	.....	.....	.....	.....	
13	.....	P?.....	0 22 37	.....	.....	.....	.....	
		S.....	0 32 33	.....	.....	.....	.....	
		L.....	0 45 ..	30	.....	.....	.....	
		L.....	0 54 ..	18	.....	.....	.....	
		F.....	3 *ca*.	.....	.....	.....	.....	
16	.....	P.....	16 07 27	.....	.....	.....	7,700	
		S.....	16 16 30	.....	.....	.....	.....	
		L.....	16 31 ..	24	.....	.....	.....	
		L.....	16 40 ..	18	.....	.....	.....	
		F.....	18 20 *ca*	.....	.....	.....	.....	
18	.....	e.....	5 35 15	.....	.....	.....	.....	
		F.....	5 40 *ca*	.....	.....	.....	.....	
25	.....	eL.....	12 34 ..	22	.....	.....	.....	
		L.....	12 40 ..	18	.....	.....	.....	
		L.....	12 50 ..	15	.....	.....	.....	
		F.....	13 20 *ca*	.....	.....	.....	.....	
26	.....	e.....	7 13 ..	.....	.....	.....	.....	
		L.....	7 22 ..	18	.....	.....	.....	
		F.....	8 20 *ca*	.....	.....	.....	.....	
29	.....	P?.....	17 31 05	.....	.....	.....	.....	
		eL.....	17 55 ..	.....	.....	.....	.....	
		L.....	18 04 ..	24	.....	.....	.....	
		L.....	18 16 ..	18	.....	.....	.....	
		F.....	19 30 *ca*	.....	.....	.....	.....	
30	.....	P.....	22 52 18	.....	.....	.....	1,400	
		S.....	22 54 48	.....	.....	.....	.....	
		L.....	22 55 40	.....	.....	.....	.....	
		F.....	23 25 ..	.....	.....	.....	.....	

CANAL ZONE. *Panama Canal, Balboa Heights.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 2	.....	P_E.....	6 06 52	.....	.....	.....	200*ca*	Probably SW.
		P_N.....	6 06 50	.....	.....	.....	.....	
		S_E.....	6 07 12	.....	.....	.....	.....	
		S_N.....	6 07 14	.....	.....	.....	.....	
		M_E.....	6 07 16	.....	*1,000	.....	.....	
		M_N.....	6 07 18	.....	.....	*1,000	.....	
		F.....	6 08 30	.....	.....	.....	.....	
9	.....	.....	.....	.....	.....	.....	.....	Slight tremosr, 16:43–16:49.

* Trace amplitude.

VERMONT. *U. S. Weather Bureau, Northfield.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 13	.....	S.....	0 39 34	.....	.....	.....	.....	
		L.....	0 48 ..	18	.....	.....	.....	
		F.....	1 10 *ca*	.....	.....	.....	.....	
18	.....	e.....	5 29 *ca*	.....	.....	.....	.....	
		F.....	5 40 *ca*	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Toronto.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 11	.....	eL.....	8 58 42	.....	.....	.....	.....	
		M.....	9 04 12	.....	*200	.....	.....	
		F.....	9 12 42	.....	.....	.....	.....	
11	.....	P?.....	13 57 42	.....	.....	.....	6,230	
		S.....	14 05 30	.....	.....	.....	.....	
		eL.....	14 13 18	.....	.....	.....	.....	
		M.....	14 16 30	.....	*300	.....	.....	
		eL.....	14 20 30	.....	.....	.....	.....	
		eL.....	14 26 48	.....	.....	.....	.....	
		F.....	14 41 54	.....	.....	.....	.....	
13	.....	e.....	0 23 24	.....	.....	.....	.....	Small micros previous to 0h. 23m. 24s.
		e.....	0 26 00	.....	.....	.....	.....	
		S?.....	0 31 06	.....	.....	.....	.....	
		eL.....	0 43 54	.....	.....	.....	.....	
		eL.....	0 57 06	.....	.....	.....	.....	
		M.....	0 57 42	.....	*500	.....	.....	
		eL.....	1 27 12	.....	.....	.....	.....	
		eL.....	1 43 48	.....	.....	.....	.....	
		F.....	2 41 00	.....	.....	.....	.....	
16	.....	L.....	7 00 24	.....	*50	.....	.....	
		F.....	7 02 30	.....	.....	.....	.....	
16	.....	e.....	16 07 48	.....	.....	.....	.....	Small micros before 16h. 33m.
		e.....	16 16 12	.....	.....	.....	.....	
		eL.....	16 33 00	.....	.....	.....	.....	
		M.....	16 37 36	.....	*500	.....	.....	
		eL.....	16 43 18	.....	.....	.....	.....	
		M2.....	16 44 36	.....	*400	.....	.....	
		eL.....	16 55 06	.....	.....	.....	.....	
		F.....	17 57 42	.....	.....	.....	.....	
18	.....	L.....	5 04 24	.....	.....	.....	.....	
		F.....	5 07 18	.....	*50	.....	.....	
25	.....	L.....	12 53 18	.....	.....	.....	.....	
		F.....	13 06 24	.....	*200	.....	.....	
25	.....	L.....	22 11 42	.....	.....	.....	.....	
		M.....	22 26 24	.....	*200	.....	.....	
		F?.....	22 50 18	.....	.....	.....	.....	
26	.....	e.....	7 26 24	.....	.....	.....	.....	
		eL.....	7 29 42	.....	.....	.....	.....	
		eL.....	7 35 00	.....	.....	.....	.....	
		M.....	7 37 12	.....	*300	.....	.....	
		F.....	?8 01 00	.....	.....	.....	.....	
29	.....	L.....	17 34 06	.....	.....	.....	.....	Micros going on at intervals.
		L.....	17 47 00	.....	*100	.....	.....	
30	.....	eL.....	22 56 12	.....	.....	.....	.....	
		eL.....	23 00 00	.....	.....	.....	.....	
		M.....	23 00 18	.....	*300	.....	.....	
		F.....	.....	.....	.....	.....	.....	Micros.

CANADA. *Dominion Meteorological Service, Victoria.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Aug. 11	.....	L.....	9 07 33	.....	.....	.....	.....	
		M.....	9 15 25	.....	*300	.....	.....	
		F.....	9 39 30	.....	.....	.....	.....	
11	.....	P.....	13 52 14	.....	.....	.....	.....	
		S.....	13 55 43	.....	.....	.....	2,070	
		L.....	13 59 11	.....	.....	.....	.....	
		M.....	14 02 09	.....	*750	.....	.....	
		F.....	14 18 31	.....	.....	.....	.....	
13	.....	P.....	0 35 14	.....	.....	.....	.....	
		L.....	0 49 46	.....	.....	.....	.....	
		eL.....	0 57 30	.....	.....	.....	.....	
		eL.....	1 01 42	.....	.....	.....	.....	
		M.....	1 04 36	.....	*1,400	.....	.....	
		F.....	2 50 49	.....	.....	.....	.....	
16	.....	L.....	7 10 18	.....	.....	.....	.....	
		M.....	7 14 16	.....	*200	.....	.....	
		F.....	7 24 11	.....	.....	.....	.....	
16	.....	S.....	16 05 47	.....	.....	.....	.....	
		iL.....	16 11 32	.....	.....	.....	.....	
		M.....	16 19 47	.....	*750	.....	.....	
		F.....	17 50 47	.....	.....	.....	.....	
18	.....	L.....	5 17 00	.....	.....	.....	.....	
		M.....	5 19 58	.....	*300	.....	.....	
		F.....	5 31 53	.....	.....	.....	.....	

* Trace amplitude.

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*
Aug. 18	.....	L.....	21 15 54	.....	.....	.....	.....
		M.....	21 19 51	.....	*250	.....	.....
		F.....	21 27 48	.....	.....	.....	.....
25	.....	L.....	12 12 32	.....	.....	.....	.....
		M.....	12 29 01	.....	*500	.....	.....
		F.....	12 48 55	.....	.....	.....	.....
25	.....	L.....	20 04 11	.....	.....	.....	.....
		M.....	20 16 58	.....	*400	.....	.....
		F.....	20 36 38	.....	.....	.....	.....
26	.....	M.....	7 10 40	.....	*250	.....	.....
		F.....	7 22 04	.....	.....	.....	.....
29	.....	L.....	17 25 46	.....	.....	.....	.....
		M.....	17 56 31	.....	*100	.....	.....
		F.....	18 32 43	.....	.....	.....	.....
30	.....	L.....	22 55 40	.....	.....	.....	.....
		M.....	22 59 09	.....	*250	.....	.....
		F.....	23 06 35	.....	.....	.....	.....

* Trace amplitude.

No earthquakes were recorded at the following stations during August, 1922:

COLORADO. *Regis College*, Denver.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory*, Cheltenham.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.

Reports for August, 1922, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.

MASSACHUSETTS. *Harvard University*, Cambridge.

MISSOURI. *St. Louis University*, St. Louis.

NEW YORK. *Cornell University*, Ithaca; *Fordham University*, New York.

CANADA. *Dominion Observatory*, Ottawa.

TABLE 3.—*Late reports (instrumental).*

CANADA. *Dominion Meteorological Service, Toronto.*

1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
July 2	.....	P.....	13 46 24	.....	.....	.....	4,450	Quake reported from various parts of Maritime Provinces on 2d, estimate of commencement varying from 5:23 to 5:30 Atlantic time, p. m.
		iS.....	13 52 36	.....	.....	.....	.....	
		iSR...	13 56 42	.....	.....	.....	.....	
		i.....	14 03 24	.....	.....	.....	.....	
		iL.....	14 04 30	.....	.....	.....	.....	
		M.....	14 07 30	.....	*2,100	.....	.....	
		eL.....	14 20 54	.....	.....	.....	.....	
		eL.....	14 43 18	.....	.....	.....	.....	
		eL.....	15 53 12	.....	.....	.....	.....	
		F....?	17 20 12	.....	.....	.....	.....	
4	.....	eL.....	13 46 12	.....	.....	.....	.....	Doubtful as to being seismic.
		M.....	13 47 12	.....	*1,200	.....	.....	

CANADA. *Dominion Meteorological Service, Victoria.*

1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
July 2	.....	P.....	13 40 12	.....	.....	.....	.....	
		iL.....	13 44 37	.....	.....	.....	.....	
		iL.....	13 45 54	.....	.....	.....	.....	
		M.....	13 48 00	.....	*3,500	.....	.....	
		F.....	16 59 53	.....	.....	.....	.....	
			VERTICAL.					
2	.....	P.....	13 41 06	2.5	.....	.....	.....	
		L.....	13 45 40	.....	.....	.....	.....	
		M.....	13 47 55	20	.....	4	.....	

* Trace amplitude.

Chart I. Tracks of Centers of Anticyclones, August, 1922. (Inset) **Departure of Monthly Mean Pressure from Normal.**

Chart I. Tracks of Centers of Anticyclones, August, 1922. (Inset) **Departure of Monthly Mean Pressure from Normal.**

(Plotted by Wilfred P. Day.)

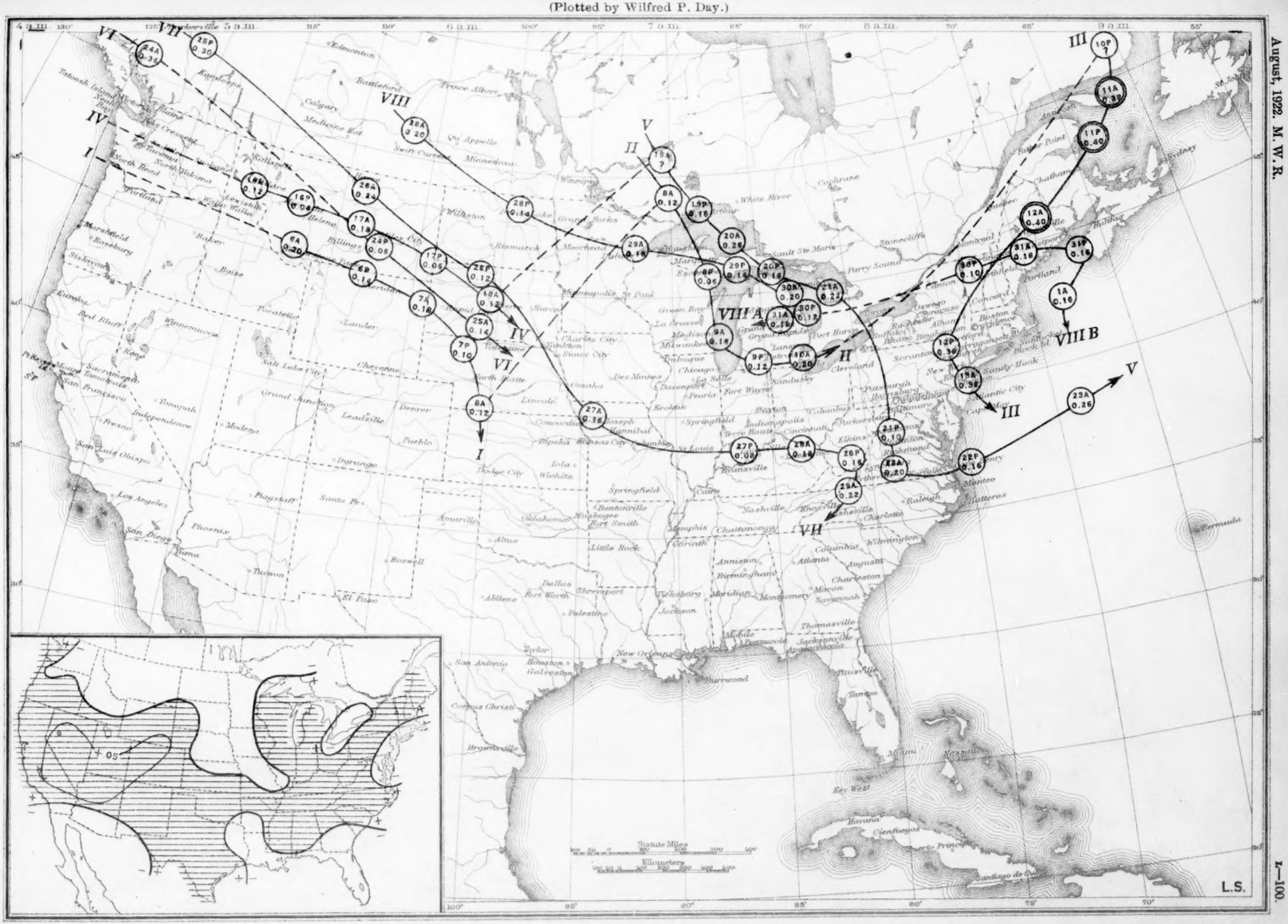


Chart II. Tracks of Centers of Cyclones, August, 1922. (Inset) Change in Mean Pressure from Preceding Month.

(Plotted by Wilfred P. Day.)

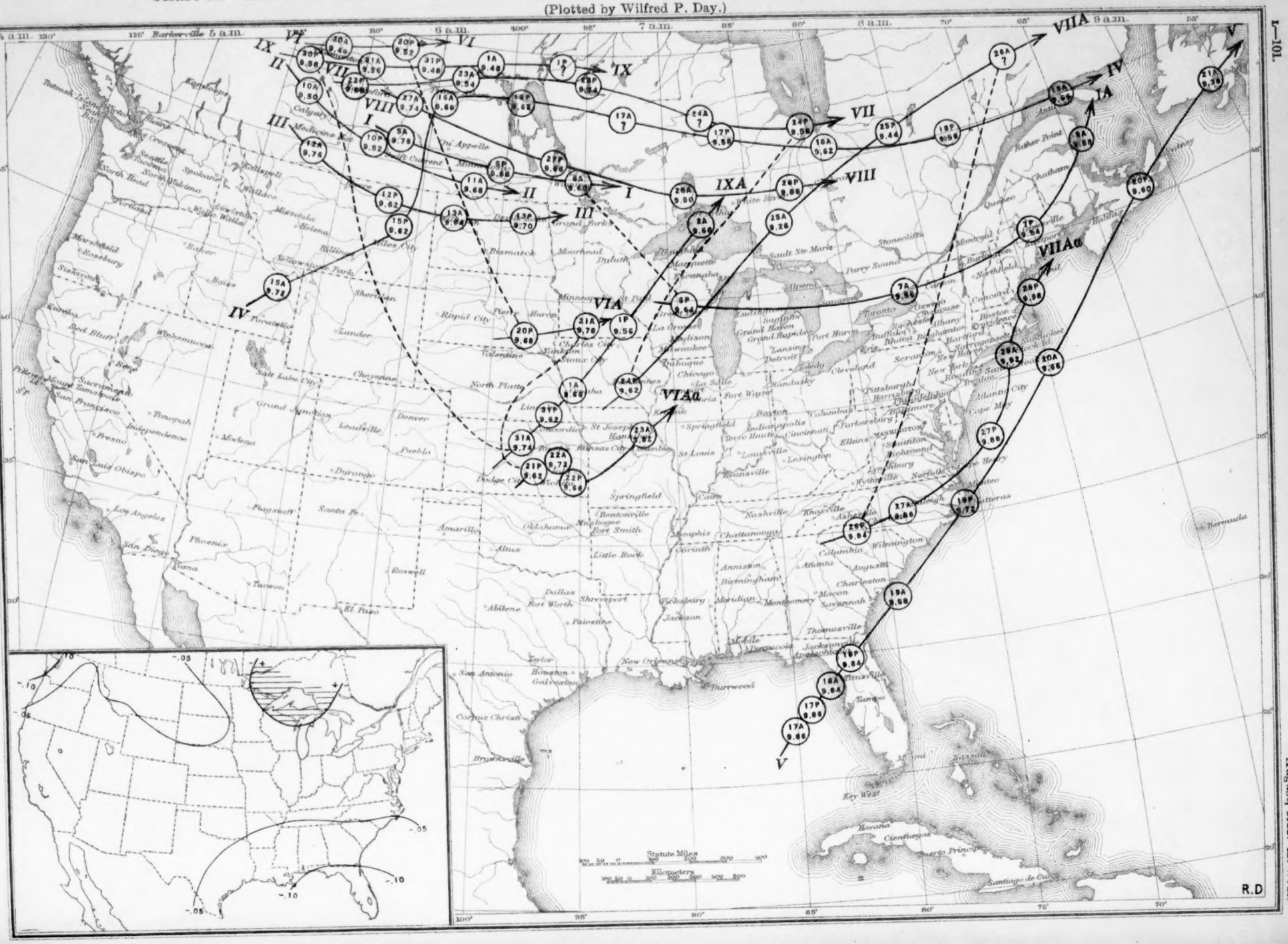


Chart III. Departure (°F.) of the Mean Temperature from the Normal, August, 1922.

Chart III. Departure (°F.) of the Mean Temperature from the Normal, August, 1922.

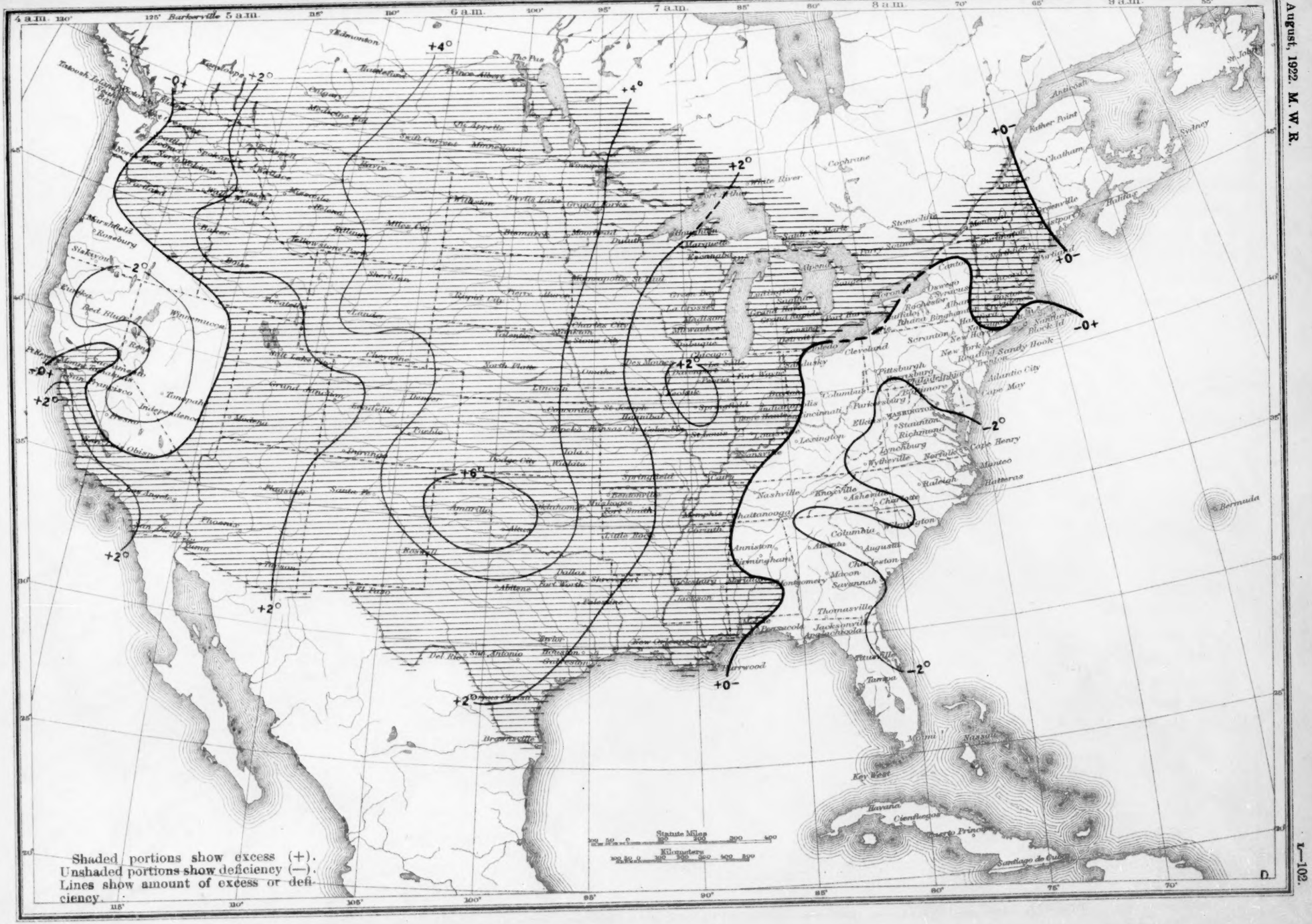


Chart IV. Total Precipitation, Inches, August, 1922. (Inset) Departure of Precipitation from Normal.

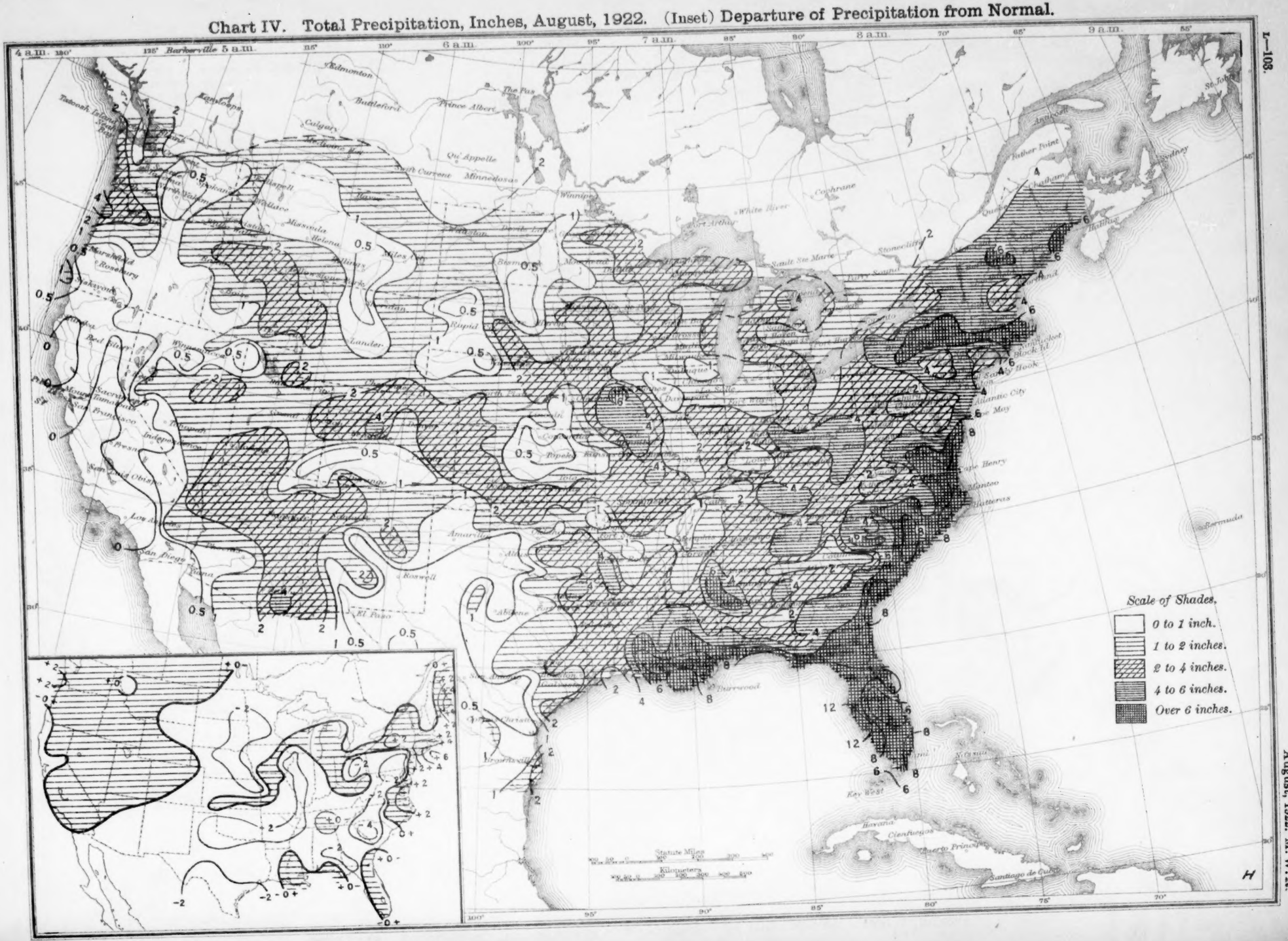


Chart V. Percentage of Clear Sky between Sunrise and Sunset, August, 1922.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, August, 1922.

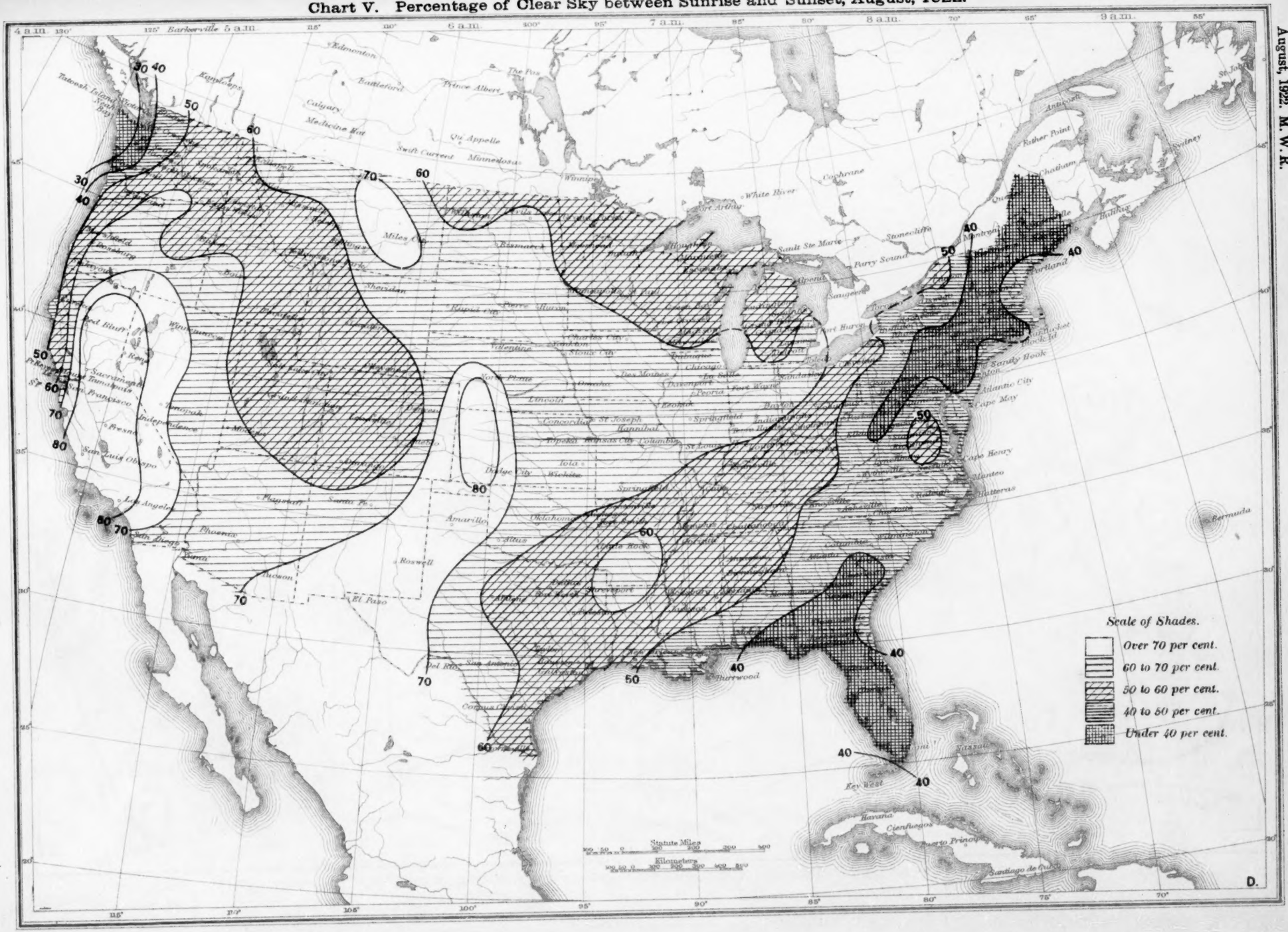
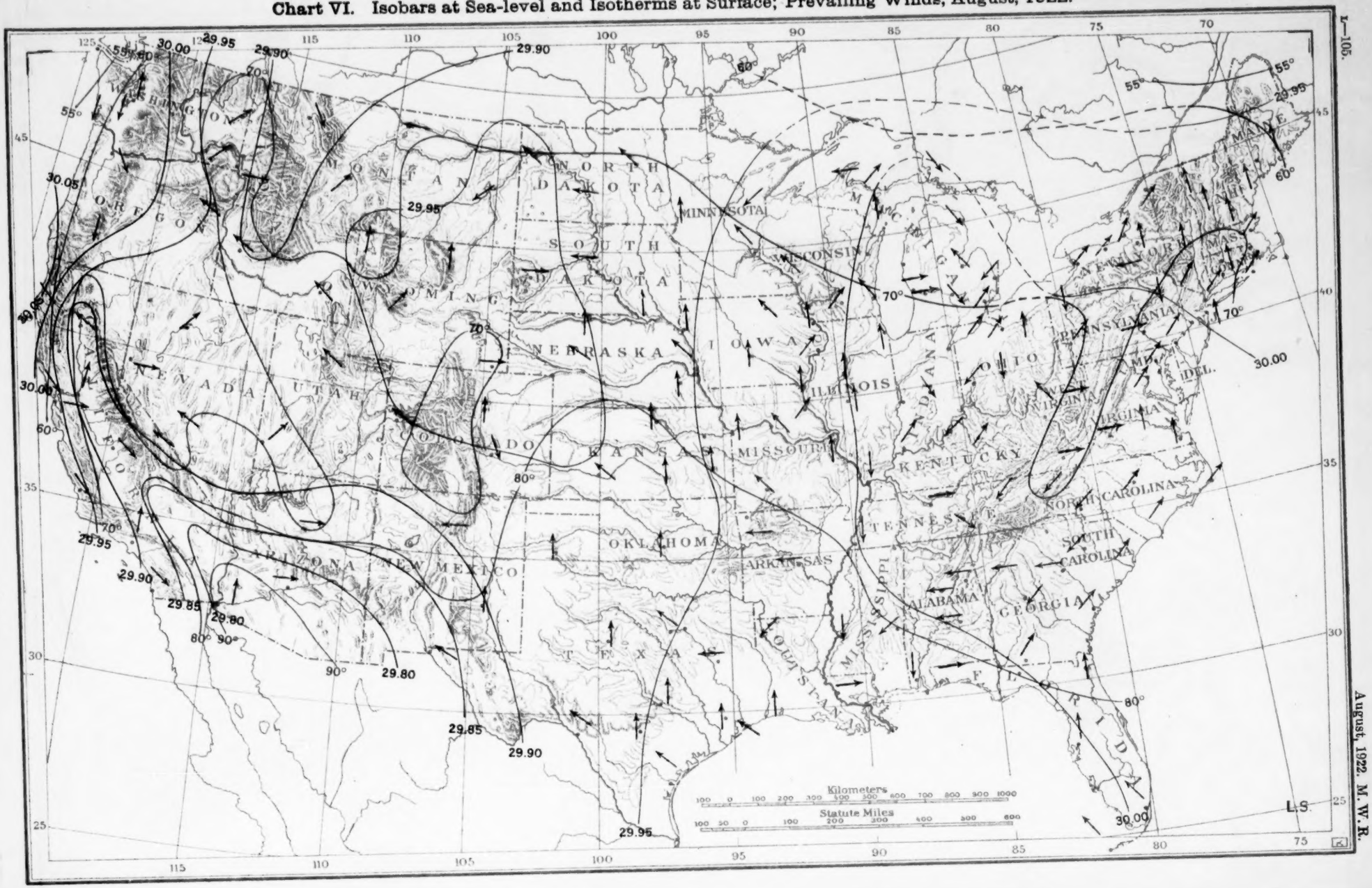


Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, August, 1922.



August, 1922. M. W. R.

—105.

Chart VIII. Weather Map of North Atlantic Ocean, August 25, 1922.

Chart VIII. Weather Map of North Atlantic Ocean, August 25, 1922.

(Plotted by F. A. Young.)

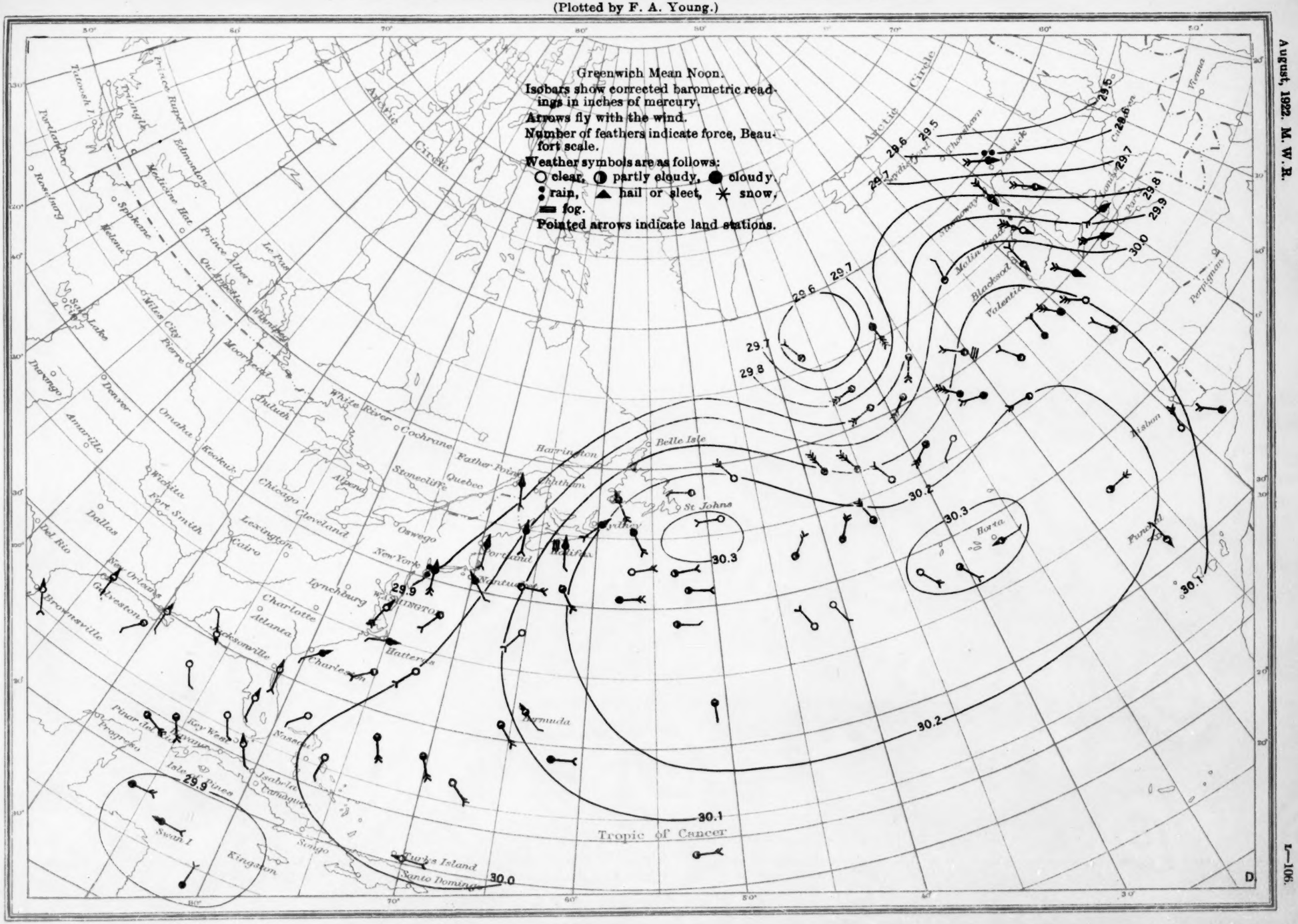
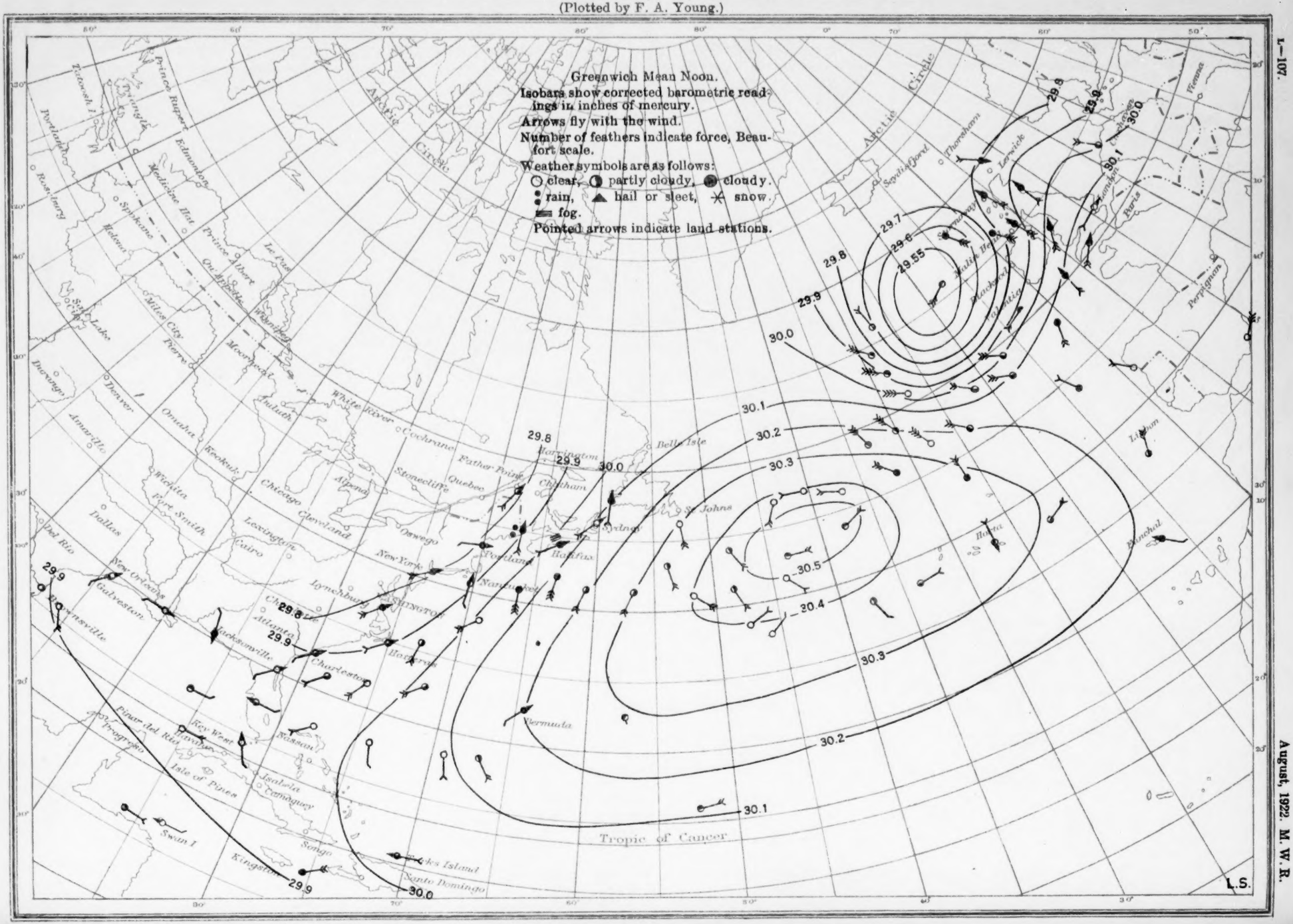


Chart IX. Weather Map of North Atlantic Ocean, August 26, 1922.

(Plotted by F. A. Young.)



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AUGUST, 1922.

CONTENTS.

CONTRIBUTIONS, ABSTRACTS, AND BIBLIOGRAPHY.

	Pages.
The earth's atmosphere as a circular vortex. A. L. Beck. Discussion by A. J. Henry. (Chart)	393–401
J. Bjerknes and H. Solberg on meteorological conditions for the formation of rain. A. J. Henry. (2 figs.)	402–404
Precipitation in Oregon. E. L. Wells. (9 figs.)	405–411
The rainfall of Brazil. A. J. Henry. (Fig.)	412–417
The Etesiens. J. S. Paraskévopoulos. (2 figs.)	417–422
Relation of sunlight to plant development. G. D. Hearn	423–424
Temperature of air in the ice cavern of Dobsina. D. L. Steiner.	424–425
Severe storms near West Chester, Pa.	425
The Charlottesville, Virginia, tornado of August 7, 1922. A. W. Giles	426–427
Tornadoes in New Mexico	427
NOTES, ABSTRACTS, AND REVIEWS:	
Distribution of weather information and warnings for the Caribbean Sea	428
A distributional and ecological study of Mount Ranier, Washington	428
Variability *vs.* uniformity in the tropics	428–429
The probable effect of climate of Russian Far East on human life and activity	429
Bibliography of meteorological literature	429
BIBLIOGRAPHY:	
Recent additions to the Weather Bureau library	429–430
Recent papers bearing on meteorology and seismology	430–431
SOLAR OBSERVATIONS:	
Solar and sky radiation measurements during August, 1922.	431
Measurements of the solar constant of radiation at Calama, Chile	431

WEATHER OF THE MONTH.

	Pages
†Weather of North America and adjacent oceans	432–437
†Notes on weather in other parts of the world	437
Details of the weather of the month in the United States—	
General conditions	438
Cyclones and anticyclones	438
Free-air conditions	438–439
The weather elements	439–441
Storms and warnings. Weather and crops—	
Weather warnings	442
Rivers and floods	442–443
Effect of weather on crops and farming operations	443
Tables—	
Climatological tables	444–448
Seismological tables	448–451

CHARTS.

	Serial Number.
I. Tracks of centers of anticyclonic areas	100
II. Tracks of centers of cyclonic areas	101
III. Departure (°F) of mean temperature from the normal	102
IV. Total precipitation, inches	103
V. Percentage of clear sky between sunrise and sunset.	104
VI. Isobars at sea level and isotherms at surface; prevailing winds	105
VII. Total snowfall, inches (not charted)	
VIII–XI. Weather maps of North Atlantic Ocean, Aug. 25–26	106–107
A. L. B. I. Weather map, January 1, 1921	108

† In marine separate